Appendix M

Riparian/Nearshore Evaluation

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M1 Introduction

This document presents a conceptual site model (CSM) of the riparian and nearshore environment along 100-BC at the Hanford Site, Washington. The 100-BC Area is located along the Columbia River and includes the 100-BC-1 and 100-BC-2 Source Operable Units (OUs), the 100-BC-5 Groundwater OU, and the adjacent surface water, saturated sediment, and aquatic biota. This CSM has been developed to further evaluate concentrations of nonradiological substances and radionuclides detected in soil, water, and sediments, and to determine whether potential transport pathways exist to these media from Hanford Site sources. The supporting evaluation of analytical data also determines if there is the potential for exposure to aquatic receptors.

M1.1 Background

Remediation of waste sites in the 100-BC Area began in 1995 under BHI-00752, *100-B/C Demonstration Project Final Report*. Remediation activities continued under the interim action Record of Decision (ROD) (*Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* [EPA/ROD/R10-99/039]) which established remedial action goals (RAGs) for protection of human health and protection of groundwater and the Columbia River (*Remedial Design Report/Remedial Action Work Plan for the 100 Area* [DOE/RL-96-17]). A final ROD has not yet been developed for the 100-BC OUs, and active groundwater remediation has not occurred. One key component needed to support development of final remedies is a baseline risk assessment.

The River Corridor Baseline Risk Assessment (RCBRA) was initiated in 2004 to characterize current and potential threats to human health and the environment (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]; DOE/RL-2007-21). In addition to waste sites located in upland areas and groundwater, the RCBRA evaluated soil, sediment, and water located in riparian and nearshore areas. The RAGs used in the interim actions addressed risks to human health from direct contact with soil and threats to groundwater from leaching from soil, but did not directly address risks to ecological receptors. The ecological risk assessment conducted as part of the RCBRA addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and nearshore zones (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* [DOE/RL-2008-46]).

The RCBRA evaluated ecological risks at representative riparian study sites across the River Corridor located adjacent to, or where they may be directly affected by, known contaminated media (groundwater seeps, soil, or sediment). The RCBRA concluded that 6 of the 22 contaminants (arsenic, chromium, lead, mercury, zinc, and total petroleum hydrocarbons for diesel [TPH-diesel]) of potential ecological concern (COPECs) identified for the riparian environment may present some level of risk for one or more of the assessment endpoint entities, based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate toxicity benchmarks, or the results of wildlife exposure analyses. The RCBRA evaluated ecological risks at nearshore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes. The RCBRA concluded that 5 of the 22 COPECs (cadmium, chromium, Cr(VI), manganese, and uranium) identified for the nearshore environment might present some level of risk for one or more of the assessment endpoint entities. Risk results that are relevant are the comparisons of COPEC concentrations to toxicity benchmarks or the results of wildlife exposure analyses (*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* [hereinafter called RCBRA Volume I (DOE/RL-2007-21)]).

The five contaminants of ecological concern (COECs) identified by the RCBRA in riparian and nearshore media mostly were metals and TPH-diesel. With few exceptions (notably chromium and Cr(VI)), there are ambient sources for the constituents in soil, sediment, and water that are unrelated to the Hanford Site. Taking into consideration what is understood to be principal threat constituents in soil and groundwater at the 100-BC Area, when compared with the contaminants identified by the RCBRA as posing ecological risks in riparian and nearshore media, additional work was warranted to better understand the CSM—the interrelationships between sources, transport mechanisms, exposure pathways, and receptors—in the riparian and nearshore environment.

M1.2 Description of the 100-BC Area

The 100-B/C Area covers 11.5 km^2 (4.5 mi^2) and is located on the south bank of the Columbia River, upstream from the rest of the Hanford Site reactor areas. The topography changes are greatest in the vicinity of the river. Away from the river, the topography of the 100-BC area is characterized by being relatively flat. The operational area within the perimeter fence has been disturbed and graded extensively by human activity since reactor construction began in the 1940s through present-day waste site remedial activities (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* [DOE/RL-2008-46-ADD3]).

The entire River Corridor, which includes the 100-BC Area, has been divided into three environmental zones for purposes of investigation (DOE/RL-2007-21; *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan* [DOE/RL-2008-46]): the upland, riparian, and nearshore aquatic zones. Summary definitions of these environmental zones are presented in Section M1.4. The upland area outside of the fence is relatively undisturbed. Spatial data provided by the Ecological Monitoring and Compliance program shows that vegetation to the east, south, and west of the perimeter fence consists primarily of three vegetation types: Sandberg's bluegrass-cheatgrass, gray rabbitbrush/Sandberg's bluegrass-cheatgrass, and small patches of big sagebrush/Sandberg's bluegrass-cheatgrass. Wildlife species observed in this area also are described in the PNNL data summary for the reactor areas along the River Corridor.

The riparian environment adjacent to 100-BC extends in a strip along the Columbia River to the north of the facility. The strip varies in width from approximately 3 to 10 m (10 to 33 ft) from the shoreline to where the upland vegetation becomes dominant (*Conceptual Site Model for the 100-B/C Pilot Project Ecological Risk Assessment* [BHI-01706]).

M1.3 Review of Previous Riparian/Nearshore Studies

Investigations that were historically conducted in the riparian and nearshore areas of the 100-BC decision area are summarized in *100-B/C Area Ecological Risk Assessment Data Quality Objectives* (BHI-01673). In addition to these historical investigations, other sampling and analytical data have been collected from riparian and nearshore areas as part of the Surface Environmental Surveillance Program (SESP). The data from the SESP are summarized in the annual environmental reports for the Hanford Site. Finally, investigations of riparian and nearshore areas were conducted as part of the RCBRA (DOE/RL-2007-21; *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan* [DOE/RL-2005-42]).

Historically, the 100-BC Area has not been identified as an area of extensive groundwater discharge to the Columbia River, although several springs have been documented along the shoreline that contained elevated levels of tritium and nitrate. Only one active spring was found in the vicinity of the 100-BC Area during the 1988 sampling activities. This spring was located just upstream from the 181-B Water Intake at about HRM 3.75. Spring locations downstream from the water intake, identified in previous studies, were visited on several occasions; however, no flow was present. Tritium and nitrate concentrations observed

during 1988 in the springwater (1100 pCi/L and 6700 ppb, respectively) were similar to those observed in 1982 and slightly lower than those present in the local groundwater during 1988 (*Investigation of Groundwater Seepage from the Hanford Shoreline of the Columbia River* [McCormack and Carlile, 1984]**;** Evans et al., 1989a and 1989b). The results of the 1988 investigation reported maximum tritium concentrations in the 100-BC area in riverbank springs and adjacent surface water at concentrations of 5,920 pCi/L, and 385 pCi/L, respectively.

Other studies conducted in the area during 1991 sampled three springs at the 100-BC Area (037-1, 038-3, and 039.2). Detectable concentrations of chromium (37, 41, and 54 µg/L), tritium (3,100, 20,600, and 13,000 µg/L) and total uranium (1.6, 1.6, and 1.5 pCi/L) were found in the springs along the 100-BC Area (*Sampling and Analysis of 100 Area Springs* [DOE/RL-92-12]).

Weiss (1993) collected four sediment samples in 1992 from two locations in the 100-BC Area. Concentrations of chromium were greater than the 95 percent upper tolerance limit (UTL) in all four samples. Zinc and lead were also detected above the 95 percent UTL. Cesium-137 was the only manmade radionuclide found (*100 Area Columbia River Sediment Sampling* [WHC-SD-EN-TI-198]).

M1.3.1 Surface Environmental Surveillance Program

In addition to the historical investigations stated above, other sampling and analytical data have been collected from riparian and nearshore areas as part of the SESP. The SESP is responsible for Sitewide and offsite environmental surveillance at Hanford. Surface environmental surveillance at the Hanford Site is a multimedia environmental monitoring effort conducted to assess onsite and offsite human health exposures to radionuclides and chemicals and to evaluate the impact of Hanford Site operations on the environment.

The SESP does not routinely monitor surface water in the vicinity of 100-BC. The nearest routinely monitored locations are surface water transects located upriver at the Vernita Bridge and immediately downriver at 100-N. Riverbank spring samples are collected from a range of locations along the shoreline of 100-BC, 100-K, 100-N, 100-D, 100-H, and 100-F, downstream from the Hanford Townsite, and at the 300 Area. Groundwater enters the Columbia River at these locations, with some contaminant concentrations higher than background concentrations.

The trends in metals concentrations in spring samples are reported to have been consistent over the past several years. With the exception of chromium, concentrations of metals in spring samples in 100-BC were below Washington State chronic ambient surface water quality criteria in "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A). Concentrations of radionuclides detected in springs in 2010 were reported to be similar to those in previous years.

M1.3.1 Groundwater and Aquifer Tube Monitoring Programs

The U.S. Department of Energy (DOE) monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the Atomic Energy Act of 1954 (AEA), the Resource Conservation and Recovery Act of 1976 (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and "Model Toxics Control Act—Cleanup" (hereinafter called MTCA [WAC 173-340]), The groundwater monitoring data relevant to the 100-BC riparian and nearshore environment are discussed further in Section M3 of this appendix.

DOE monitors groundwater quality along the Columbia River by collecting samples from aquifer tubes and riverbank seeps (springs). The rise and fall of the Columbia River create a zone of interaction that influences contaminant concentrations and groundwater flow patterns. Water samples from aquifer tubes and riverbank seeps nearly always represent a mixture of river water and approaching groundwater.

In general, the degree of dilution by river water decreases with depth in the aquifer near the river shoreline. The degree of dilution also varies by location and with seasonal river cycles (*Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]). The aquifer tube and seep data relevant to the 100-BC riparian and nearshore environment are discussed further in Section M3 of this appendix.

M1.4 Approach to CSM Development

As described previously, the objective for developing this CSM is to provide a tool for evaluating the potential for contaminants in riparian and nearshore media to be associated with releases from Hanford-related sources. The foundation for developing the CSM begins with the definition of environmental zones presented in the RCBRA (DOE/RL-2007-21). They are:

- **Nearshore aquatic zone:** the nearshore aquatic zone includes the surface water of the Columbia River from the area that is permanently inundated by river water (that is, the low-water mark, commonly referred to as the "green line," where the periphyton remain green year-round) up to the riparian zone.
- **Riparian zone:** the riparian zone is a transition area between the aquatic environment in the nearshore zone and the upland zone. The riparian zone extends from the shoreline of the Columbia River to the point on the riverbank where upland vegetation becomes dominant. The riparian zone typically is narrow and varies in width depending on the slope of the riverbank.
- **Upland zone:** the upland zone consists of land that extends inland from the riparian zone and is situated approximately 3 m (10 ft) above the river high-water mark. The upland zone generally is dry and not readily influenced by river flow. Recharge to groundwater in this zone occurs largely from precipitation. The upland zone includes operational areas in the 100-BC Area decision areas and generally is where waste sites are located.

These environmental zones are depicted on Figures M-1 and M-2.

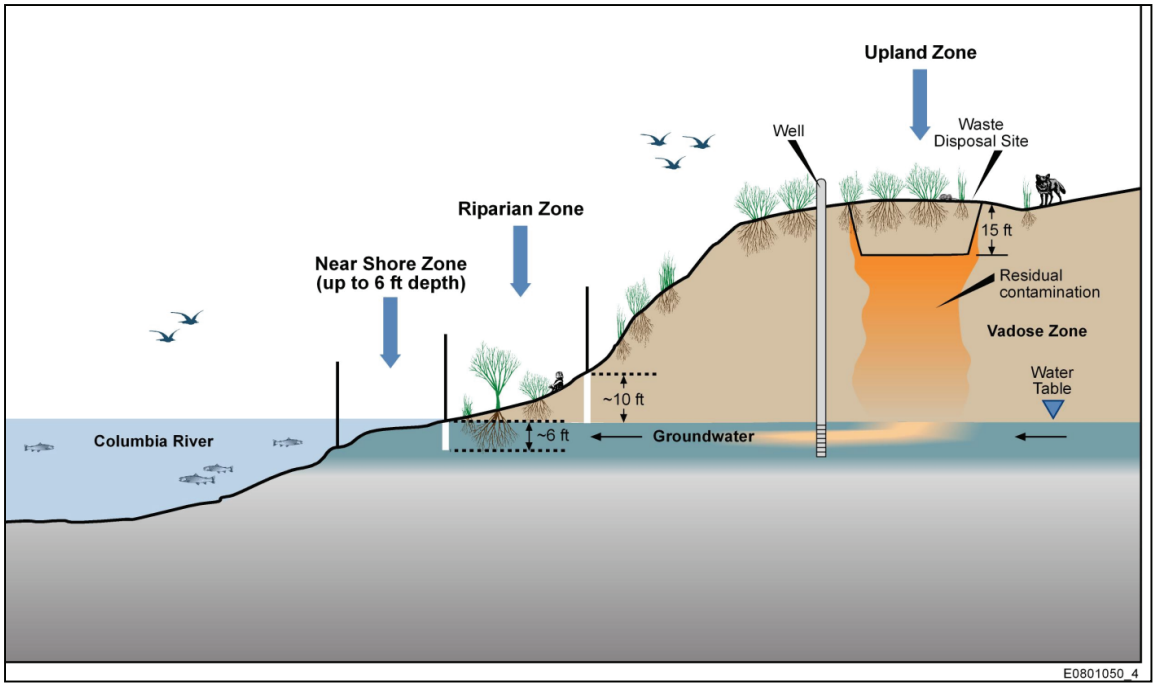

Figure M-1. Environmental Zones in the Riparian/Nearshore Area

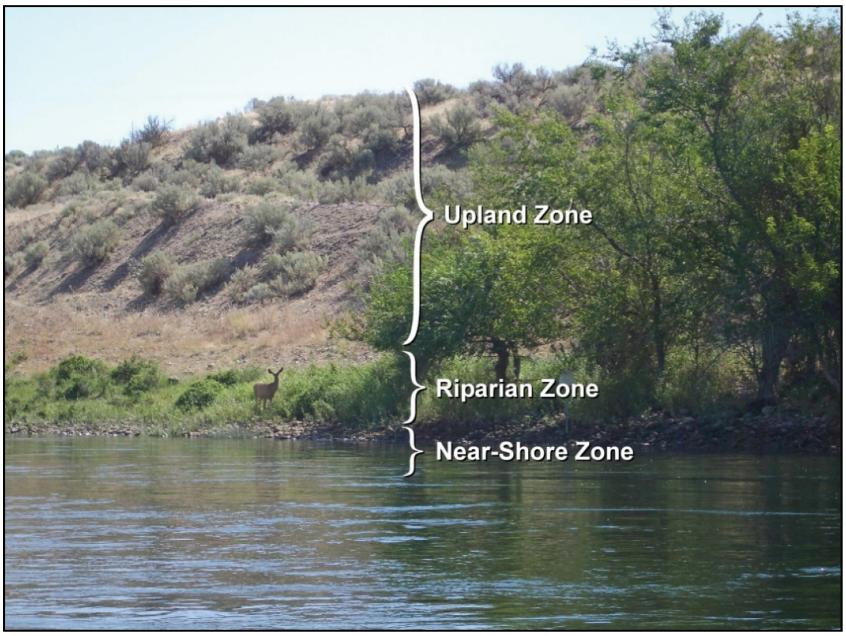

Figure M-2. Photograph Depicting the Environmental Zones

Potential exposure pathways from source OUs and the underlying groundwater OU located in the upland zone have been traced to media in the riparian and nearshore zones. An exposure pathway can be described as the physical course that a contaminant takes from the point of release to a receptor. The route of exposure is the means by which a contaminant comes into contact with a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of contaminant release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard.

An additional consideration for contaminants detected in riparian and nearshore zones is a contaminant source, or sources, unrelated to Hanford Site operations that have been transported and deposited via the river. These other sources also are discussed as part of this CSM. Identification of potential exposure pathways in the riparian and nearshore zones is described in Section M2.

Once the potential exposure pathways are identified and described, sampling and analytical data from various media are evaluated. The objectives for this evaluation include depicting the relative concentrations in the various riparian and nearshore media and evaluating data quality. Media in the riparian and nearshore areas that have been sampled include groundwater, pore water, seeps/springs, surface water, sediments, biota, and soil. The results from this data evaluation are combined with the exposure pathway information (described previously) to determine whether contaminant concentrations located at exposure points are potentially associated with Hanford Site activities. The data evaluation is described in Section M3.

An evaluation of potential ecological risks in riparian and nearshore zones was conducted as part of the RCBRA (DOE/RL-2007-21). The results from this evaluation are summarized in Section M4. These results, which identified COECs, are compared with the results from the data evaluation in Section M3 to determine whether those COECs might be associated with Hanford Site activities.

M2 Evaluation of Riparian and Nearshore Exposure Pathways

This section describes the sources, release and transport mechanisms, environmental media through which contaminant transport occurs, and exposure points in the riparian and nearshore zones. This section provides the framework for the data evaluation that is presented in Section M3.

M2.1 Sources

A total of 150 waste sites are found in the 100-BC Area, located principally in the upland zone (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* [DOE/RL-2008-46-ADD3]). As described in *Conceptual Site Model for the 100-B/C Pilot Project Ecological Risk Assessment* (BHI-01706), the riparian environment immediately adjacent to the 100-BC Area is composed of a relatively narrow vegetative zone usually less than 10 m (33 ft) wide along the river north of the facility. This strip varies in width from approximately 3 to 10 m (10 to 33 ft) from the shoreline to where the upland vegetation becomes dominant (*Conceptual Site Model for the 100-B/C Pilot Project Ecological Risk Assessment* [BHI-01706]). A limited number of the 100-BC waste sites are of interest with regard to the riparian/nearshore CSM. In addition to these waste sites, groundwater in the 100-BC-5 OU is potentially a source for contaminant release to riparian and nearshore media.

M2.1.1 Waste Sites and Soils

The waste sites located close to the riparian zone in the 100-BC Area OU are presented on Figure M-3. Brief descriptions of these sites are presented in the following paragraphs. The nature and extent of contamination has been characterized or is currently being characterized for these waste sites. Although it is not known if there are potential releases or exposure pathways from these sites, their proximity to the riparian area makes them candidates for consideration as potential sources in this evaluation.

100-B-2. This site is located east of the 181-B Pump House and outside the exclusion area perimeter fence, and is associated with the 181-B Pump House. The site consists of a trench that was constructed to receive backwash filter back flush from the 181-B Pump House. The trench was fed by a single 30 cm (12 in.) pipeline that originated at the backwash filter. The pipe is approximately 0.9 m (3 ft) below grade and enters the trench from the west. Before construction of the trench, the back flush water was returned directly to the Columbia River. This site is classified as no action and is inactive.

116-B-7. The site was located at the top of the river bank, northwest of 116-B-11 (107-B Retention Basin), upstream from site 132-B-6 (1904-B-32 Outfall). Outfalls were open, reinforced concrete structures that directed the water through either the river discharge pipelines or through spillways. The spillways were concrete flumes used when the river pipelines were blocked, damaged, or undergoing maintenance. Cooling water released from the reactor went to a retention basin located between the reactor building and the river. Water retention permitted thermal cooling and decay of short-lived radioisotopes prior to river discharge. As reactor production increased, the hold-up period decreased. The basins also served to hold up flow of effluent with high radioactive isotope concentrations resulting from fuel element failure. This effluent was isolated and diverted, either by gravity or pumping, to an open pond area or crib. The pond or crib filtered the effluent through the ground. The cooling water discharged into the upper chamber of the concrete outfall structure, flowed through a bar grillwork, and fell about 6.1 m (20 ft) to the lower chamber of the outfall structure. The cooling water then overflowed from the lower chamber into the discharge pipe to the river. The outfall was excavated, sampled and backfilled to match the surrounding grade during remediation, and is now closed out.

100-B-24. The site was located northwest of 116-B-11 Retention Basin and upstream from the 132-B-6 Outfall with the remaining portion of the spillway 18 m (60 ft) downstream from, and parallel to, the river effluent pipeline. This spillway was an alternate discharge point for the 116-B-3 Outfall structure. The 100-B-24 Spillway (also referred to as a flume) was constructed of concrete and led from the 116-B-3 Outfall structure to the river shoreline. The spillway was to be used for an emergency effluent release or if the 100-B-15 River Effluent Pipelines were blocked, damaged, or undergoing maintenance. The site was associated with the 100-B-15 River Effluent Pipelines and the 116-B-1 Outfall structure. Originally, the 1904-B1 Outfall, Spillway (flume) and river pipelines were entered into the Waste Information Data System (WIDS) as one site number (116-B-1). Because of remediation project needs, the Outfall structure, the River Effluent Discharge lines (100-B-15), and the Spillways (flumes) (100-B-24) have been documented as separate waste sites. The site has been sampled and found to meet the requirements for reclassification to "no action." The flume has been decommissioned and backfilled.

132-B-6. The site is located north of the northeast corner of 116-B-11 (107-B Retention Basin) bank, directly north of the east end of 116-B-11 (107-B Retention Basin), and downstream from 116-B-7 (1904-B-1 Outfall structure), at the top of the riverbank. A dirt road leading to the site is crossed by a vegetation-free outfall structure wall that was left intact when the structure was backfilled to grade. The site received effluent from the 100-B process effluent lines (100-B-8), the 100-B process sewer lines (100-B-14), and discharged effluent via the 100-BC River Effluent Pipelines (100-B-15) and flumes (100-B-15:1). The site has been remediated and closed out.

100-B-25. This site was located north of the northeast corner of the 116-B-1 (107-B Retention Basin) and downstream from 116-B-7 (the 1904-B-1 Outfall). The site consisted of only a spillway (also referred to

as a flume.) This spillway was constructed of concrete and led from the 132-B-6 Outfall structure, via a heavy riprap extension on the end of the concrete spillway, to the river shoreline. During decommissioning projects in the 1980s, the spillway walls were collapsed and the structure was covered with clean soil. The spillway was an alternate discharge point for the 132-B-6 Outfall structure and was planned to be used only if the 100-B-15 River Effluent Pipelines were blocked, damaged, or undergoing maintenance. The site is associated with the 100-B-15 River Effluent Pipelines and the 132-B-6 Outfall structure. The site has been remediated and reclassified to Interim Closed Out.

132-C-2. This site consists of a river effluent pipeline (river line) located just north of the 116-B-11 (107-B Retention Basin) and downstream from 116-B-7 (1904-B1 Outfall) and 132-B-6 (1904-B32 Outfall). The site received effluent from the 100 C process effluent lines (100-B-6) and discharged effluent via the 132-B-2 Outfall, 100-BC river effluent pipelines (100-B-15) and/or flumes (100-B-26). The outfall structure was removed during the Remedial Action and Waste Disposal (RAWD) project in the winter of fiscal year 2001. The site has been remediated and closed out.

100-B-15. The river lines are located in the Columbia River, adjacent to the 100-BC Area. The lines extend north into the main channel of the river from three outfall structures located near the river shore. This site includes the 100-BC Area river effluent pipelines (river lines) 1904-B1 (116-B-7), 1904-B2 (132-B-6), and 1904-C (132-C-2) that extend from each of the three outfalls into the main channel of the Columbia River

The site is associated with the 116-B-7 (1904-B1 Outfall), 132-B-6 (the 1904-B2 Outfall), and structures: 132-C-2 (the 1904-C Outfall); the 100-B Reactor Cooling Water Effluent Underground Pipelines (100-B-8), the 100-B Area Process and Sanitary Sewer Underground Pipelines (100-B-14), the 100-C Reactor Cooling Water Effluent Underground Pipelines (100-C-6), and the 100-C Area Process and Sanitary Sewer Underground Pipelines (100-C-9); the 107-B Retention Basin (116 B-11), the 107-B Liquid Waste Disposal Trench (116-B-1), the 107-C Retention Basins (116-C-5), and the 107-C Liquid Waste Disposal Trench; and 100-B-24 (the 1904-B1 Spillway), 100-B-25 (the 1904-B2 Spillway), and 100-B-26 Spillway (and the 1904-C Spillway).

Originally, the 1904-B1, 1904-B2, and 1904-C outfalls, spillways (flumes) and river pipelines were included in the outfall site. Because of remediation project needs, the outfall structures, the river effluent discharge lines (100-B-15), and the spillways (flumes) (100-B-24, 100-B-25 and 100-B-26) have been documented as separate waste sites. During 2001 and 2002, the three outfall structures were removed, the associated spillways were covered with clean soil, and the exposed (outfall) ends of all pipelines left in place were plugged with poured concrete. This site has been remediated and is inactive.

128-B-3. This site was located northeast of the northeast comer of the 100-B perimeter road on the plateau above the river shoreline. The 128-B-3 site is a Coal Ash and Demolition Waste Site in an area where dumping and burning of waste material had occurred. The site was visible in a 1968 aerial photo and appeared to have been divided into a construction debris dumping area to the south and a combustible waste burning area to the north. The site was separated into the two sections by an ash-covered roadway. At the site's southern edge was an area of vegetation-free gravel, covered with what was described as a "white-colored spray." The site has been remediated and reclassified; however, institutional controls are to be maintained on the river embankment area to prevent activities that would mobilize residual contaminants to travel to groundwater or the river. Institutional controls will be maintained until the results of a baseline risk assessment can be considered (for a final site remedy, closure).

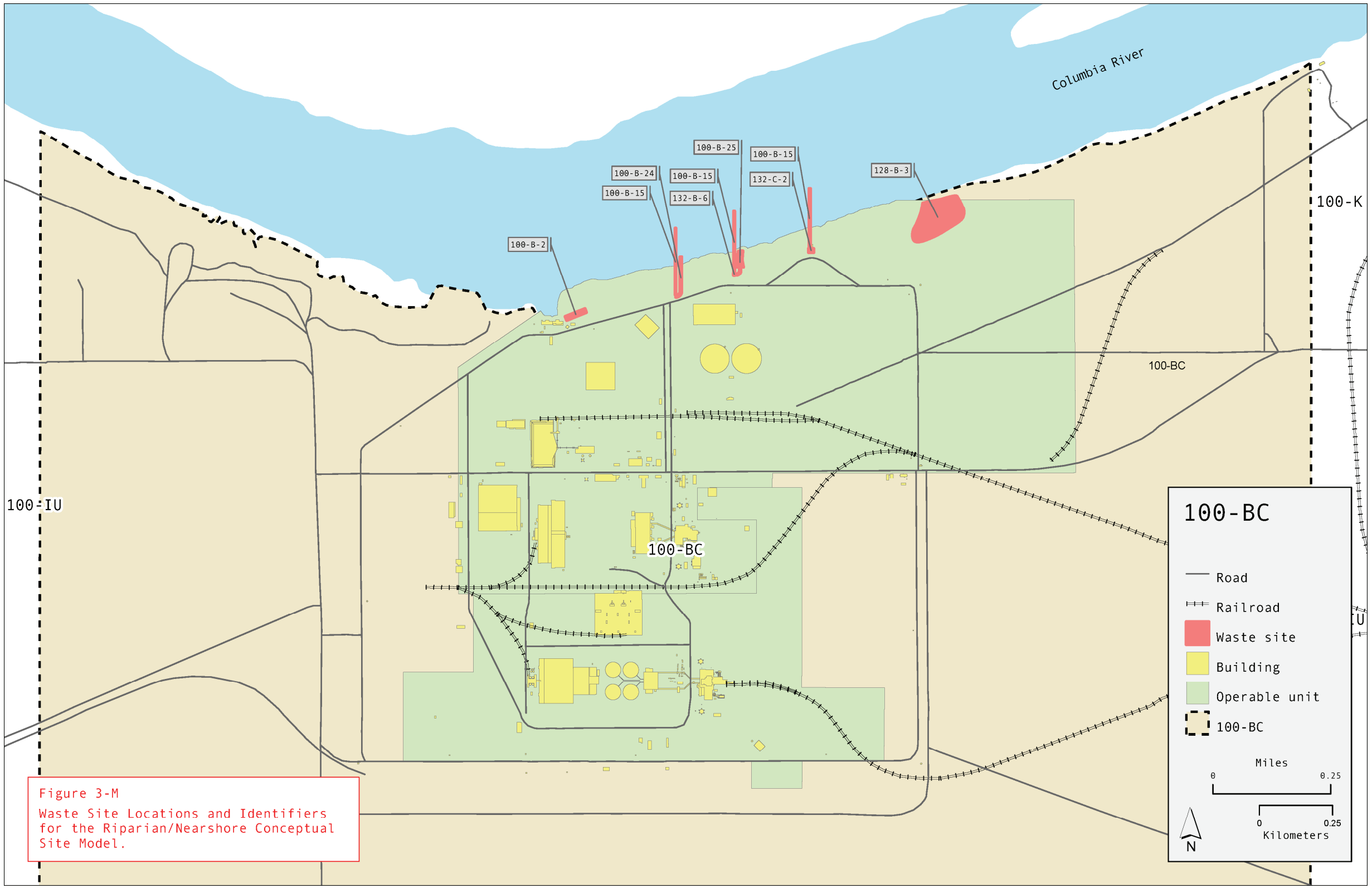

Figure M-3. Waste Sites of Interest for the Riparian/Nearshore

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M2.1.2 Groundwater

The 100-BC-5 OU includes groundwater impacted by contaminant releases from facilities and waste sites within 100-BC. Most of the facilities and waste sites are associated with former operation of the 100-B and 100-C reactors and their support facilities.

Principal groundwater issues for the 100-BC-5 OU involve (1) localized chromium plumes of uncertain origin near the 100-B and 100-C reactors, (3) radiological contamination associated with past discharges to the ground near the 100-B and 100-C reactor buildings, and (4) loss of shielding water from the fuel storage basins associated with each reactor building. Groundwater beneath 100-K flows generally toward the northwest to the Columbia River. Contaminants of interest in the OU include Cr(VI), carbon-14, nitrate, strontium-90, technetium-99, trichloroethene, and tritium. These constituents are of interest primarily because their concentrations exceed drinking water standards. The results discussed in Chapter M6 indicate that Cr(VI), nitrate, carbon-14, strontium-90, trichloroethene, and tritium warrant further evaluation in the feasibility study (FS).

Generally, groundwater in the unconfined aquifer of the Hanford Site flows from recharge areas in the elevated region near the 100-BC western boundary toward the Columbia River on the eastern and northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. At the 100-BC Area the groundwater flows to the northeast toward the Columbia River, and is generally between 15 m (50 ft) and 31 m (100 ft) beneath surface-grade level, depending on the distance from the Columbia River. During high river stage, recharge occurs from the Columbia River as indicated by a much shallower gradient and reversed flow direction. When river stage is high, the flow direction periodically shifts toward the southeast (*Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units* [PNNL-14287]). High river stages can be more than 3 m (9.8 ft) higher than low river stages. The river stage also can fluctuate several feet over short periods (that is, hours to days) based on operations at the upstream Priest Rapids Dam. Changing river stage can influence groundwater elevations far inland into the Hanford Site from the river (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*[DOE/RL-2010-11]).

M2.2 Contaminant Release and Transport Mechanisms

Release and transport mechanisms potentially most likely associated with the occurrence of Hanford Site contaminants in riparian and nearshore zones are overland transport from waste sites, and contaminant leaching from the vadose zone to underlying groundwater, followed by lateral transport in groundwater.

M2.2.1 Overland Transport from Waste Sites

Hazardous and radioactive substances that are in surface materials can be transported away from facilities or known waste sites by surface runoff following precipitation events. Overland flow is water flow over the ground surface that occurs from precipitation, either rainfall or snowmelt that is greater than obstraction demands (interception, evapotranspiration, or infiltration). In addition, overland flow can occur from the spillage of process effluent that historically had been discharged into liquid waste disposal units. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site into other areas such as the riparian or nearshore locations. Factors that affect overland flow include slope of the ground surface, soil texture, vegetative cover, and frequency of precipitation.

There are relatively few examples of overland flow potentially from 100-BC sites into riparian or near-shore areas. Contamination of riparian and nearshore media would likely be more associated with historical releases from outfall structures from the reactors and retention basins.

M2.2.2 Contaminant Leaching from Waste Site Soils to Groundwater

Contaminated wastes released from reactor support facilities, cooling water processing facilities, underground piping, liquid waste disposal sites, solid waste disposal sites, and surface spills were primary sources of contamination in 100-BC during operations, and secondary sources may have developed in vadose zone and aquifer materials. The potential for transport of contaminants within the vadose zone and aquifer at 100-BC is affected by the impacts of historical high-volume liquid waste disposal during operations on vadose zone moisture and the water table, the development of secondary sources of contamination in the vadose zone material, groundwater/surface water interactions, and the effect of Columbia River stage fluctuations on contaminant transport. The fate and transport of contaminants detected in vadose zone and groundwater above applicable criteria is discussed in detail in Chapter 5 of the remedial investigation/feasibility study (RI/FS) report.

One concept important for understanding contaminant fate and transport in 100-BC is the difference between site conditions during Hanford operations (1955 to 1971) and the current site conditions, which have developed since reactor operations ended.

M2.2.3 Transport in Groundwater

Groundwater flow and contaminant transport in the unconfined aquifer is also affected by Columbia River stage fluctuations. The increase in the river stage during the spring freshet pushes water inland and causes water table elevation increases throughout the 100-BC Area. Consequently, the hydraulic gradient is altered and less water flows into the river from the aquifer. During the low river stage in the fall, groundwater flow toward the river dominates. Depending on the location within 100-BC, direction variability in flow occurs because of these competing influences (Figure M4).

The groundwater system is highly dynamic, being influenced by regional groundwater conditions, the local site remediation efforts, and the daily and seasonal variations of river stage. The main features of the current conceptual model are:

- Flow under the Site and near the banks is generally assumed to be perpendicular to the river.
- Deeper geologic formations are assumed not to contribute to shallow groundwater or observed river exchanges along the riverbank.
- The daily variability of river stage creates a complex zone of mixing within the near-bank groundwater system.
- Springs observed on the riverbanks are attributed to bank storage of river water, and site groundwater discharging to the river when river stage drops.
- Site groundwater generally discharges to the banks via springs and through the bottom of the Columbia River immediately adjacent to the Site.

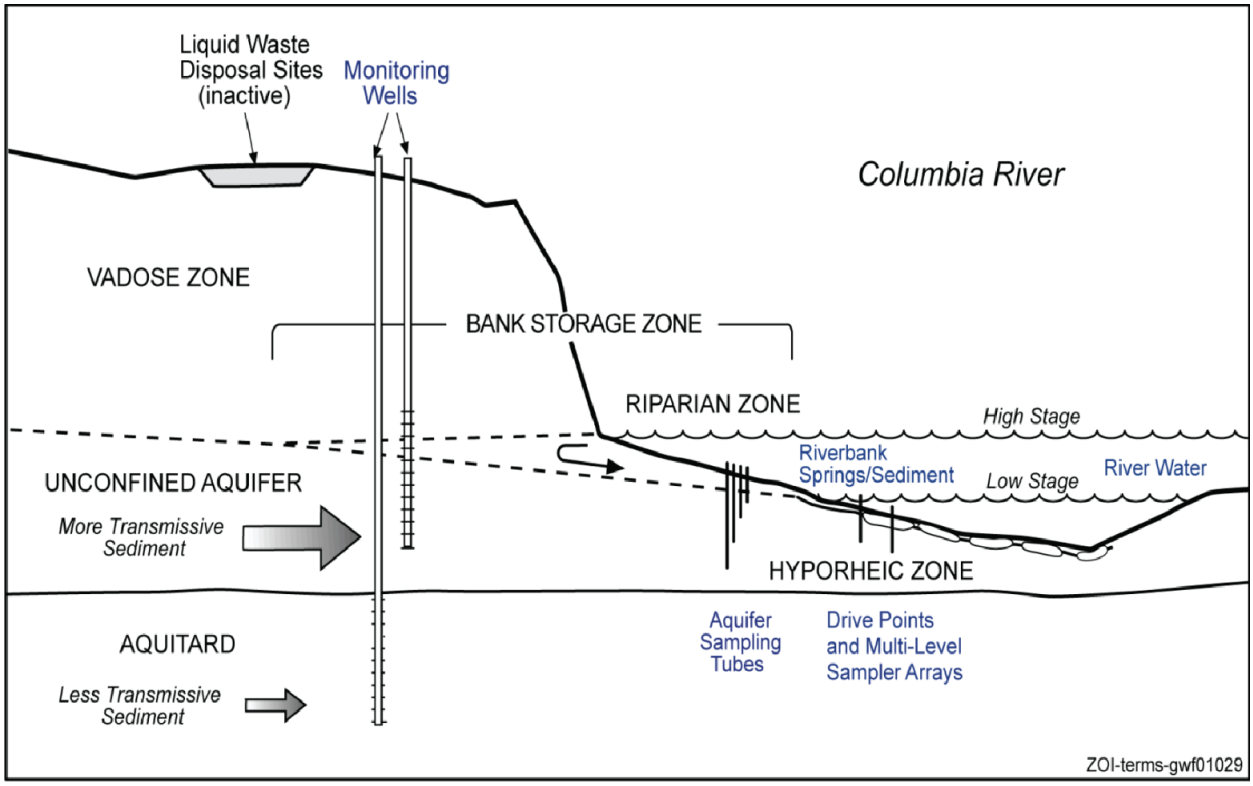

Figure M-4. Conceptual Model of Groundwater-Surface Water Interaction at the Hanford Site

The site conceptual model needs to clearly include the transient nature of water exchange in this setting at multiple time scales (Figure M-4). For example, a daily 3 m (9.8 ft) change in river levels superimposed with seasonal changes or alterations of site groundwater flows by remediation efforts likely causes seasonal shifts in the regional groundwater flow system that will consequently impact groundwater-surface water exchange locations and rates. The complex geologic setting, aquifer heterogeneity, and transient nature of the surface water and groundwater results in a complex groundwater flow system. During major spring discharge events, river water may enter the banks and the adjacent groundwater system upstream from the Site and move laterally parallel to the river for some distance before discharging back into the river (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]).

M2.3 Exposure Points in Seeps, Surface Water, Sediments, and Riparian Soils

The RCBRA (DOE/RL-2007-21) showed a cross-section of the river that defined the study zones to be the upland zone, the riparian zone, nearshore aquatic zone, and aquatic zone as a vertical panel that extends down from the surface into the subsurface to some undetermined depth when, in reality, they are three-dimensional zones that change size over time. In particular, it is the vertical distribution of the receptors beneath the river and in the deposits adjacent to the river (that is, the depth to which they are found, or bottom of the system) that potentially have the greatest implications for remedial actions, because the mechanisms of dilution and mixing of groundwater may not be as effective at greater depths and so there is greater potential for exposure to contaminants from groundwater.

In the studies of the Columbia River at the Hanford Site, the term hyporheic zone has been used as a general term to describe the zone of all groundwater and surface water mixing. Receptors in the riverbed and benthic and hyporheic zones can be exposed to contaminated (1) groundwater, (2) groundwater

surface-water mixtures, or (3) surface water. These distinctions become important when identifying, from analytical results in groundwater and surface water, COPECs that are related to Hanford Site operations.

Investigation of riparian area soils was conducted as part of the RCBRA. The riparian assessment evaluated ecological risks at 18 study sites potentially affected by contamination from Hanford Site sources. Eleven study sites were selected from locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment). These sites were located along the Columbia River shoreline near the operating areas (100-BC, 100-K, 300 Area, etc.) and included six sites with relatively elevated contaminant concentrations and five sites with relatively low contaminant concentrations. Historical data and radiation surveys were used to determine the general contaminant levels at each site. One of these riparian study sites was located near the 100-BC decision area and is described as follows:

- **Riparian 2a.** This site was located in the corner of a major bend in the river by the 100-BC Area. The area is a major depositional zone that is rarely scoured during high river stages (~300+ kcfs), consisting largely of cobbles with a heavy matrix of sediment. The width of the site ranged between ~10 m and 40 m (~34 and 131 ft) and encompassed approximately 4,500 m^2 (48,438 ft^2) of shoreline habitats. Being predominately a depositional environment and sediment substrate, there is also a relatively large stand of willow (*Salix* sp.*)* in the center of the investigation area.

Soil samples were collected from study sites and from reference sites using MULTI INCREMENT® sampling (MIS) methodology. This method was designed to obtain representative estimates of the average contaminant concentrations in the study site and control the sampling fundamental error and the grouping and segregation errors associated with measuring soil concentrations. Soil MIS represents surface soils of the 0 to 15 cm (0 to 6 in.) depth interval using a systematic random design across a 200 m (656 ft) long investigation area. The contaminants detected in these soil samples include inorganics (metals), organic compounds including polychlorinated biphenyl (PCB) aroclors, polycyclic aromatic hydrocarbons, phthalates and chlorinated pesticides, and radionuclides. Inorganics in riparian soil in 100-BC that had been identified as COPECs in the RCBRA and that were evaluated further were arsenic, barium, cadmium, chromium, Cr(VI), copper, lead, mercury, and zinc. Organic compounds detected in 100-BC soils were not identified as COPECs in the RCBRA, with the exception of bis-2-ethylhexyl phthalate. Radionuclides were not identified as COPECs; however, radionuclides detected in riparian area soils included cesium-137, cobalt-60, europium-152, plutonium-238, plutonium-239/240, strontium-90, and uranium isotopes. Biota sampling conducted in these sites is described in detail in the RCBRA (DOE/RL-2007-21). Assessment of ecological risks based on the biota sampling is described further in Section M4 of this appendix.

Nearshore study sites sampled as part of the RCBRA in 2005 were located within three key contaminant plumes originating from Hanford Site operations (Cr(VI) at 100-K and 100-D, strontium-90 at 100-N, and uranium at the 300 Area [*100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan* (DOE/RL-2005-42)]). Ten additional study sites sampled in 2006 were located in selected regions where Hanford's legacy materials were known or suspected to have been deposited. Study sites located in proximity to 100-BC are summarized below:

- **Nearshore Site 2a.** This site was located in the corner of a major bend in the river by the 100-BC Area. The area consisted of a major depositional zone that was rarely scoured during high river stages (300,000 cfs or more), and consisted largely of cobbles with a heavy matrix of sediment. A substantial population of freshwater mussels existed in this area, and the site did not contain any suitable salmonid spawning habitat.

Sediment, pore water, and surface water samples were collected from these sites. Further discussion of these data is incorporated into the data evaluation presented in Section M3. Biota sampling performed at these sites is described in the RCBRA (DOE/RL-2007-21). Assessment of ecological risks based on the biota sampling results is described in Section M4. Contaminants detected principally in the sediment, pore water, and surface water samples were inorganics (metals and anions) and radionuclides.

M2.4 Routes of Potential Exposure and Receptors

A range of terrestrial and aquatic plant, invertebrate, and wildlife species were considered in the ecological risk assessment conducted as part of the RCBRA (DOE/RL-2007-21), and are discussed in detail in that ecological risk assessment. A conceptual model depicting the exposure pathways is provided on Figure M-5, followed by a depiction on Figure M-6 of the measurement endpoints used to evaluate those pathways to the receptors identified. These measures are discussed in Section M.3 and M.4. The measures of abiotic environmental media (for example, groundwater or soil) are compared to effects levels presented in Section M.3.2. Biotic measures and a weight of evidence are discussed in Section M.4.

M2.4.1 Riparian Zone Exposure Pathways

The boundaries of the riparian zone are defined as extending from the water line of the Columbia River to the upper edge of the riverbank where upland vegetation becomes dominant. The riparian zone along the shoreline of the Columbia River is typically narrow because of the steep riverbank. Potential sources of contamination include seep water (upwelling of groundwater in the riparian zone) and associated sediment. Additionally, contaminants originating from past releases in operational areas could have been transported through several release mechanisms affecting the soil surface within the riparian zone.

Contaminants could have been transported to the riparian zone through surface drainage from the following:

- Precipitation contacting surface soil or waste and running off of the associated waste site
- Landslides or slumping of contaminated soil from upland operational areas into the riparian zone
- Fugitive dust transported through wind or work activities on the waste sites

The primary exposure pathways and release mechanisms in the riparian zone transporting the contaminants from the source, via environmental media, to potential receptors include the following:

- External radiation from contaminated surface soil or sediment
- Generation of dust emanating from surface soil to ambient air from wind
- Volatilization of chemicals emanating from surface soil or sediment to ambient air at the site
- Transport of contaminants in groundwater to release locations in the riparian area (that is, seeps)
- Shoreline seeps/springs containing contaminants

Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

Through transport pathways (for example, upwelling of groundwater in a riverbank seep), secondary media (such as plants) may become contaminated through root uptake from soil or groundwater/seeps. These secondary contaminated media, in turn, may be consumed by receptor species contributing to exposure.

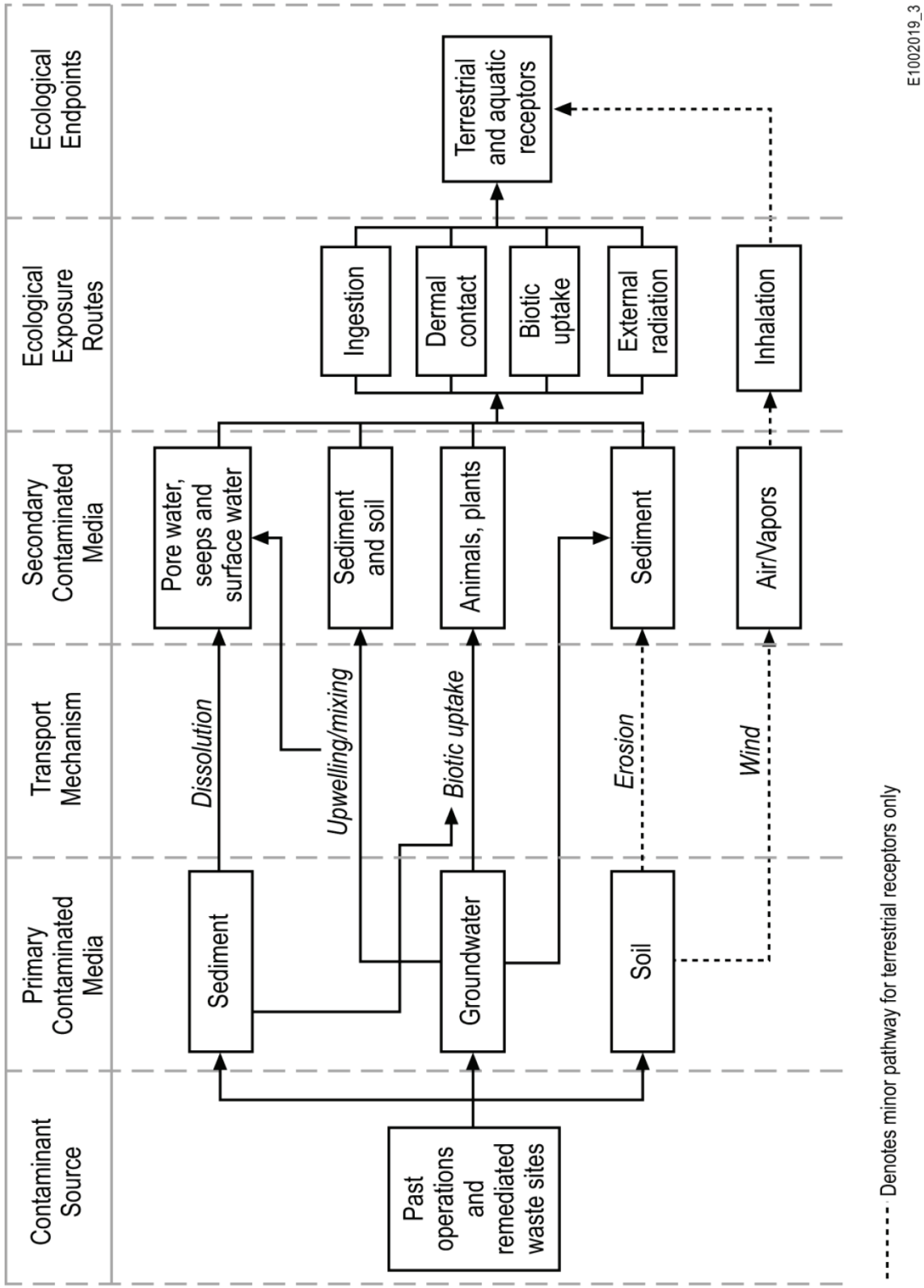

Figure M-5. Ecological Conceptual Exposure Model for the Aquatic Environment (Combined Riparian and Aquatic Nearshore Zones)

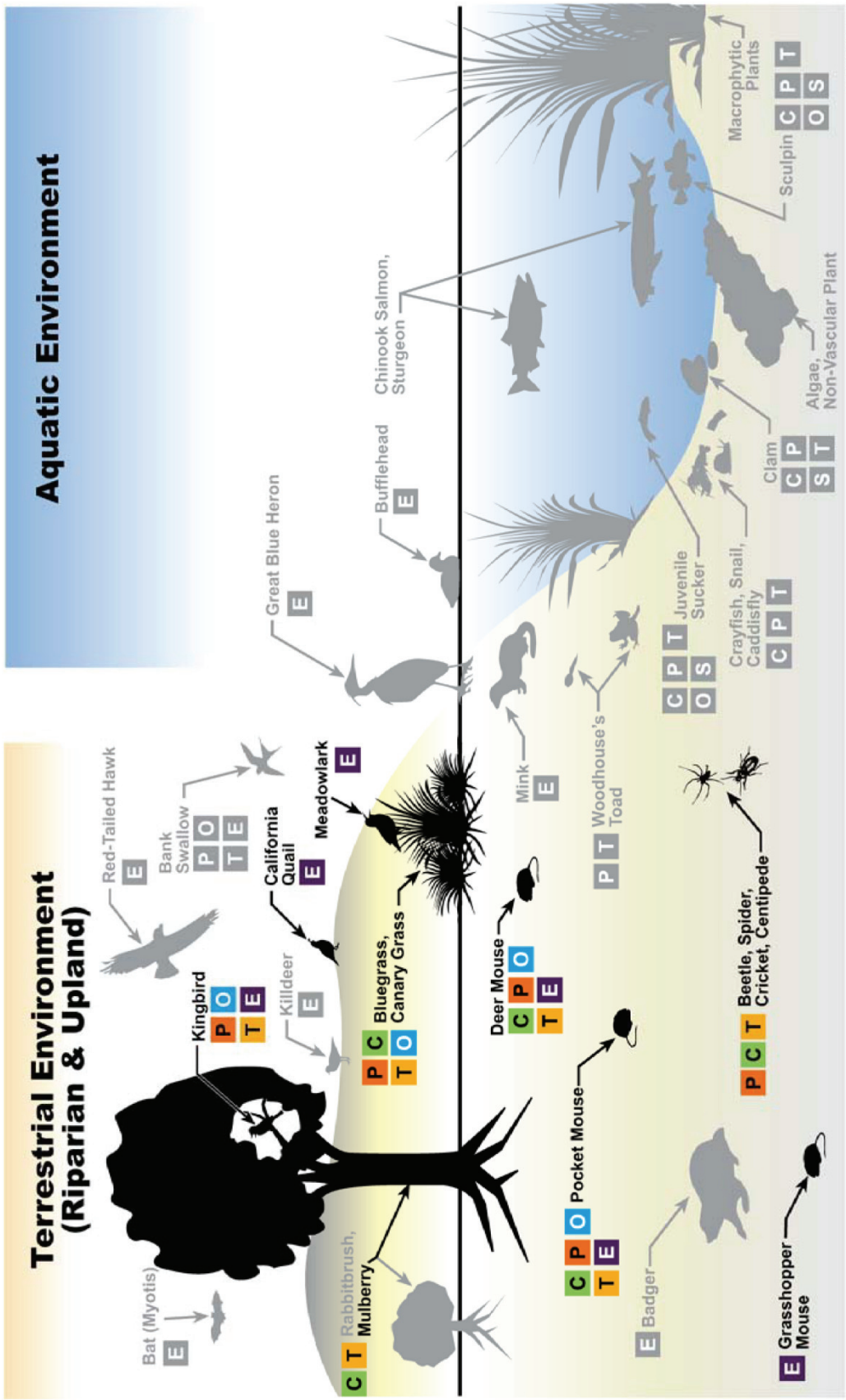

Figure M-6. Summary of Endpoints and Measures Evaluated in the Riparian Environment

The following ecological exposure routes were identified for the riparian zone:

- Incidental or intentional ingestion of contaminated soil, sediment, water, or biota
- Dermal contact with contaminated soil, sediment, water, or biota
- Exposure of terrestrial and aquatic vertebrates, invertebrates, and plants to external radiation emitted by contaminated soil or foodstuffs
- Uptake or absorption of soil-, sediment-, or water-bound contaminants
- Inhalation of contaminated dust or volatilized contaminants

The riparian ecological exposure routes that were evaluated in the ecological risk assessment include ingestion of contaminated soil, seep water, and biota. Exposure from external radiation was considered by comparing soil radioactivity to radionuclide-specific biota concentration guidelines. Although there is a potentially complete exposure pathway via inhalation of fugitive dust and dermal contact with chemicals, these are generally considered minor exposure routes for ecological receptors (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]).

M2.4.2 Nearshore Aquatic Zone Exposure Pathway

The nearshore aquatic zone is defined as the area that is permanently inundated by river water, extending from the seasonal low-water mark (that is, a "green line" where the periphyton [sessile algae] remains green year round) into the river to a water depth of about 2 m (6 ft). A nearshore study boundary depth of 2 m (6 ft) was selected to optimize the ability to measure potential influence of emergent groundwater and other potential Hanford Site contaminant sources within the Columbia River. Potential sources of contamination within the nearshore aquatic zone include contamination along the Columbia River shoreline at riverbank seeps/springs and other submerged locations where upwelling groundwater mixes with the river water.

The primary release mechanisms transporting the contaminants from the source via environmental media, to potential receptors include the following:

- Transport of contaminants in groundwater to mixing areas in the nearshore area
- Seeps containing contaminants that flow into the river
- External irradiation from surface sediment containing contaminants (receptor irradiation from sediment replaces release and transport)
- Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

Secondary media such as surface or pore water, sediment, or biota may become contaminated through transport pathways such as biotic uptake or upwelling of groundwater. These secondary contaminated media, in turn, may be contacted or consumed by receptor species, contributing to exposure.

The following ecological exposure routes were identified for the nearshore zone:

- Incidental or intentional ingestion of contaminated sediment, pore water, surface water, or biota
- Dermal contact with contaminated sediment, biota, pore water, or surface water

- Exposure of aquatic vertebrates, invertebrates, and plants to external radiation emitted by contaminated sediment or biota
- Uptake or absorption of sediment- or water-bound contaminants

The nearshore ecological exposure routes that were quantified in the ecological risk assessment include ingestion of contaminated sediment, surface water, and biota. Exposure from external radiation was considered by comparing contaminated sediment and water to radionuclide-specific biota concentration guidelines. Although there is a potentially complete exposure pathway via dermal contact with chemicals, this is generally considered a minor exposure route for ecological receptors (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]).

M2.4.3 100-BC River Effluent Pipeline Investigations

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the two inactive 100-BC effluent pipelines remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA (DOE/RL-2007-21) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

In 1984, the *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The dose rates measured for direct contact with the interior of the pipe surfaces were less than 1 mrem/hr, and readings on the exterior were below the instrument's detection capability. Because the half lives of all of these radionuclides is less than 30 years, the activity levels have declined by a factor of two to five and are no longer expected to be ecological risk drivers.

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR reactors.

Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, there are no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations as a result of decay
- Inaccessible location
- Unavailability of significant contaminants to affect human health and the environment

Accordingly, no further action is considered for below-river effluent pipeline waste sites 100-B-8 and 100-C-6 in this RI/FS.

M3 Data Evaluation

Analytical data collected from the riparian and nearshore zones were evaluated to focus on the COPECs that could be related to Hanford Site operations. This data evaluation encompassed groundwater (characterized by near-river wells and aquifer tubes), seeps/springs, surface water, sediments, and riparian soil data, obtained from a range of Hanford Site sources. These sources included groundwater monitoring activities documented in the annual groundwater monitoring reports; sampling of sediments, seeps, and surface water conducted as part of the SESP; and sampling of sediments, pore water, surface water, and riparian soils conducted as part of the RCBRA.

These analytical results were compared with ecological benchmarks and criteria to confirm whether or not these should be identified as COPECs. Analytical data quality, in particular filtered versus unfiltered analyses of water samples, was taken into consideration in making the comparisons with benchmarks and criteria. The spatial relationships of contaminant concentrations in surface water, pore water, and groundwater were evaluated to address considerations of whether or not detected contaminants were related to Hanford Site operations (that is, originated from upland groundwater sources) or reflected ambient background conditions.

M3.1 Data Sources and Data Processing

The dataset used in this evaluation consisted of sampling and analysis data collected from 6 nearshore monitoring wells, 44 aquifer tubes, 2 pore water locations, 5 seep/spring locations, and 13 surface water locations within the boundaries of the 100-BC-5 OU. A list of the groundwater wells and aquifer tubes used in this evaluation is provided in Table M-1. Pore water, seep/spring, and surface water sampling locations are based on sampling locations identified in the RCBRA. Figure M-7 shows the sampling locations for each type of water media, riparian soil, and sediment.

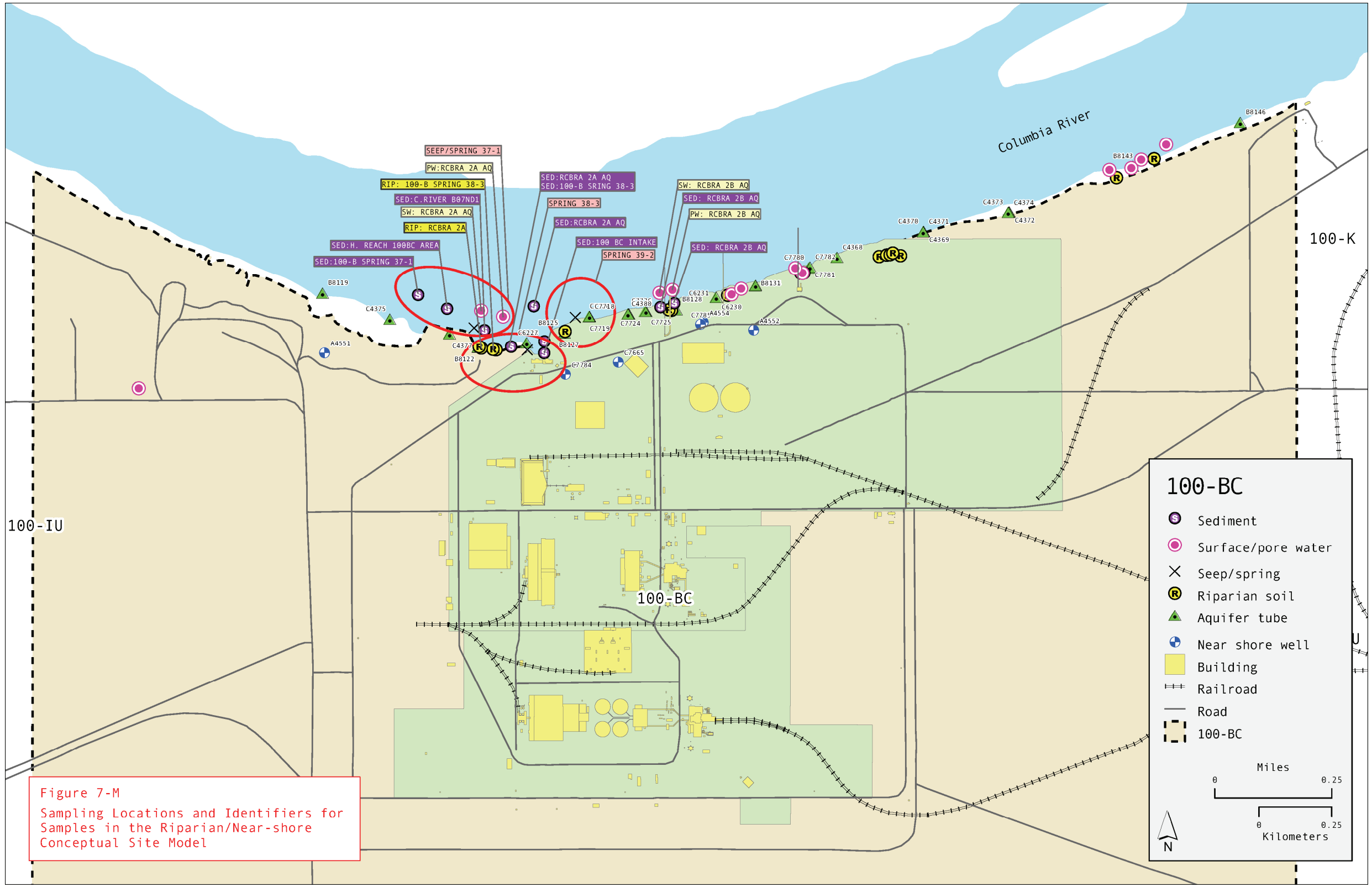

Figure 7-M
Sampling Locations and Identifiers for Samples in the Riparian/Near-shore Conceptual Site Model

Figure M-7. Sampling Locations Evaluated in the Riparian/Nearshore Conceptual Site Model

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The dataset was obtained from the Hanford Environmental Information System (HEIS) and included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed to eliminate unusable results and thus identify one set of results per sampling location and date of sample collection. The data processing steps are described in the following subsections.

M3.1.1 Laboratory and Data Validation Flags

Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged and/or qualified sample results are used in identifying contaminants of interest:

- Sample results flagged with a "U" qualifier, or combination of qualifiers that include a "U," such as a "UJ," are considered nondetected results.
- Sample results without a "U" qualifier are considered detected concentrations, including results with no qualifier or with a "J" qualifier.

Sample results that are rejected and flagged with an "R" qualifier are not used in identifying COPCs.

M3.1.2 Analytes Reported by Numerous Analytical Methods

Often analytes are reported by more than one analytical method, resulting in multiple results for the same analyte from the same location and sample data. When analytes are reported by more than one analytical method for a sample, the set of data that best represents the actual concentrations is retained. For example, the gamma spectroscopy method provides concentration results for the uranium isotopes; however, uranium concentrations reported by a uranium-isotope-specific method are preferred.

M3.1.3 Field Duplicate and Field Split Results

Field quality control (QC) samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (for example, monitoring well) on the same date, resulting in more than one sample per location/date. The following criteria are used to reduce multiple sample results for an individual location/date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

M3.2 Identification of Ecological Screening Levels

Ecological screening levels (ESLs) were used for comparison with analytical results in water, soil, and sediment to identify COPECs, and were derived from available sources of chemical-specific applicable relevant and appropriate requirements (ARARs), readily available soil screening levels (SSLs), or site-specific preliminary remediation goals (PRGs) for plants and invertebrates or wildlife. A summary of

ESLs for water are listed in Table M-2. A summary of the plant/invertebrate and wildlife ESLs are listed in Table M-3. A summary of the lower and upper threshold sediment ESLs is provided in Table M-4.

M3.2.1 Ecological Screening Levels for Water

The sources of water ESLs are listed below:

- "Phosphorous toxicity in Chara" (Blindow, 1988).
- *Ambient Water Quality Criteria for Fluoride* (British Columbia Ministry of the Environment [BCMOE], 1995).
- California Regional Water Quality Control Board (CRWQCB).
- *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1 (*DOE/EH-0676).
- *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002).
- *Ambient Water Quality Criteria for Antimony (III)* (U.S. Environmental Protection Agency [EPA], 1988).
- *National Recommended Water Quality Criteria* (EPA, 2009).
- *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision* (ES/ER/TM-96/R2).
- "Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake Trout (*Salvelinus Namaycush*) and Lake Whitefish (*Coregonus Clupeaformis*)" (McGurk et al, 2006).
- "Water Quality Values" (Michigan Department of Environmental Quality [MDEQ], 2011).
- "Detrimental Effects of Nitrite on the Development of Benthic Chironomus Larvae, in Relation to Their Settlement in Muddy Sediments" (Neumann et al, 2001).
- "Derivation of Ecotoxicity Thresholds for Uranium" (Sheppard et al, 2005).
- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A).
- *Vanadium Pentoxide and Other Inorganic Vanadium Compounds* (World Health Organization [WHO], 2001).

The ESL was selected from lowest of the available values for protection of aquatic receptors, as listed above.

M3.2.2 Ecological Screening Levels for Soil

The sources of the plant/invert ESLs and wildlife ESLs are described below. In general, values for metals are PRGs, while those for organics are SSLs. The specific values and the sources and basis for each value are provided in Table M-3.

Plant/invertebrate ESLs. PRGs for plant and invertebrates are documented in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). When appropriate, these represent thresholds of toxicity to plants and invertebrates at Hanford and are reflective of site-specific conditions. SSLs were employed when a PRG

was not available as documented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). The most appropriate value for each COPEC was selected from:

- Site-specific NOECs from samples collected in 2011as documented in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158).
- Site-specific no observed adverse-effect concentrations (NOAECs) from samples collected in 2006 and 2007 as documented in the RCBRA (RCBRA Report [DOE/RL-2007-21]).
- Site-specific PRGs for lead and arsenic presented in *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards* (Ecology Publication 11-03-006).
- Hanford Site background:
  - *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE/RL-92-24).
  - *Hanford Site Background: Part 2, Soil Background for Radionuclides* (DOE/RL-96-12)).
  - *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data* (DOE/RL-95-55).
  - *A Review of Metal Concentrations Measured in Surface Soil Samples Collected on and Around the Hanford Site* (PNNL-18577)).
  - *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038).
- *Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* (OSWER Directive 9285.7-55).
- MTCA "Tables," Table 749-3, "Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals" (WAC 173-340-900).
- Oak Ridge National Laboratory (ORNL) screening benchmarks:
  - *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (ES/ER/TM-85/R3).
  - *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes: 1997 Revision* (ES/ER/TM-126/R2).

Wildlife ESLs. PRGs for wildlife represent sets of site-specific values derived in order to be protective of wildlife that are found or that represent feeding guilds at the Hanford Site. PRGs rely on desktop food chain models that are effectively equivalent to those published by EPA (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]) and Ecology (MTCA "Tables," Table 749-3, "Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals" [WAC 173-340-900]). PRGs typically use a combination of literature-based information for the species specifically found at the Hanford Site, while incorporating site-specific tissue data into the food chain models. Wildlife PRGS are documented in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311) and SSLs are documented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784).

M3.2.3 Ecological Screening Levels for Sediment

ESLs for sediment are the same as those used in the RCBRA and in the *Columbia River Component Risk Assessment, Volume I: Screening Level Ecological Risk Assessment* (hereinafter called CRC [DOE/RL-2010-117]) and come from a variety of published sources. When available, preference was given to values published in the *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054). Other sources were used when a value was not available in this report with preference toward specificity toward datasets from the Pacific Northwest.

M3.3 Identification of Contaminants of Interest - Water

After extracting and processing the 100-BC-5 OU groundwater analytical dataset from HEIS, a multi-step screening process was used to identify initial contaminants of interest (COIs). The steps are:

- Apply exclusion criteria
- Identify nondetected analytes
- Identify analytes with maximum detected concentrations less than their respective ESLs
- Identify analytes with maximum detected concentrations greater than their respective ESLs

M3.3.1 Apply Exclusion Criteria

The first step in the COI identification process is to apply certain exclusion criteria. Analytes that meet the exclusion criteria were eliminated as a COI. The only exclusion criterion used was the absence of toxicity information for an analyte; if there were no ESLs available as described in Section M3.2.1, that analyte was not carried into the next step of the data evaluation process. Analytes that did not meet any of the exclusion criteria were carried forward into the next step.

The analytes in nearshore groundwater wells, aquifer tubes, pore water samples, and surface water samples that do not have ESLs are summarized in Tables M-5 through M-8. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum method detection limits (MDLs) are also provided in Tables M-5 through M-8.

M3.3.2 Identify Nondetected Analytes

The next step in the groundwater COI identification process was to identify nondetected analytes. Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations, with adequate detection limits), are eliminated as COIs. All analytes detected at least once were carried forward to the next step.

Analytes that were not detected in near-river groundwater wells, aquifer tubes, pore water, seep/spring, or surface water samples are summarized in Tables M-9 through M-14.

M3.3.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

This step identifies analytes with maximum concentrations less than ESLs. In this screening step, the maximum concentration of each analyte detected in groundwater was compared to its ESL, to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its ESL, the analyte was eliminated as a contaminant of interest.

A list of analytes with maximum concentrations less than their ESL is presented in Tables M-15 through M-19. With regard to groundwater, the focus of this analysis has been on analytes that are not identified as the contaminants that have already been identified for remedial alternatives evaluation in the FS, including hexavalent chromium, chloroform, trichloroethene, tritium, and strontium-90. Further discussion of these contaminants is provided in Section 4.3.2 of the RI/FS Report.

M3.3.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than their respective ESLs. Such analytes are likely to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its ESL, the analyte is identified as a COI. Analytes with maximum detected concentrations greater than their respective ESLs are described below. Tables M-20 through M-23 provide a summary of the analytes with maximum detected concentrations greater than their respective ESL for each water media. Table M-24 summarizes the results for all water media and all contaminants of interest described below.

3.3.4.1 Aluminum

Groundwater. Aluminum was detected in 39 of 48 unfiltered groundwater samples (81 percent frequency). Aluminum concentrations in unfiltered samples range from 7.1 to 123 µg/L. Of the 39 detected results, one sample was reported with a concentration greater than the ESL of 87 µg/L. Aluminum was detected at monitoring well 199-B2-16 (123 µg/L). The concentration greater than the ESL was flagged with a "BD" qualifier indicating the analyte was detected at a value less than the contract required detection limit (RDL), and the analyte was reported at a secondary dilution factor. All MDLs are less than the ESL.

Aluminum was detected in 16 of 40 filtered groundwater samples (40 percent frequency). Aluminum concentrations in unfiltered samples range from 11 to 156 µg/L. Of the 16 detected results, one sample was reported with a concentration greater than the ESL of 87 µg/L. Aluminum was detected at monitoring well 199-B2-16 (156 µg/L). The concentration greater than the ESL was flagged with a "BDC" qualifier indicating the analyte was detected at a value less than the RDL, the analyte was reported at a secondary dilution factor, and the analyte was detected in both the sample and the QC blank. Most MDLs are less than the ESL.

Aquifer Tubes. Aluminum was detected in all five filtered aquifer tube samples (100 percent frequency). Aluminum concentrations in filtered samples range from 261 to 4,200 µg/L. All five samples were reported with concentrations greater than the ESL of 87 µg/L. All five concentrations were flagged with a "Y" review qualifier indicating the results are suspect.

Pore Water. Aluminum was detected in one of two unfiltered aquifer tube samples (50 percent frequency). The single aluminum concentration in unfiltered samples was reported at location RCBRA 2A AQ (399 µg/L). All MDLs are less than the ESL of 87 µg/L.

Seep/Spring. Aluminum was not detected in filtered seep/spring water samples (one sample). The single MDL was greater than the ESL of 87 µg/L.

Surface Water. Aluminum was detected in one of two unfiltered surface water samples (50 percent frequency) at a concentration of 36 µg/L. The single aluminum concentration in unfiltered samples is less than the ESL of 87 µg/L.

3.3.4.2 Chromium

Groundwater. Chromium was detected in 48 of 55 unfiltered groundwater samples (87 percent frequency). Chromium concentrations in unfiltered samples range from 1.1 to 69 µg/L. Of the 48 detected results, one sample was reported with a concentration greater than the ESL of 64 µg/L. Chromium was detected at monitoring well 199-B3-47 (69 µg/L).

Chromium was detected in 50 of 53 filtered groundwater samples (94 percent frequency) with concentrations ranging from 0.87 to 56 µg/L. Chromium concentrations in filtered samples are less than the ESL of 64 µg/L.

Aquifer Tubes. Chromium was detected in 15 of 20 unfiltered aquifer tube samples (75 percent frequency) with concentrations ranging from 6.2 to 45 µg/L. Chromium was detected in 20 of 24 filtered aquifer tube samples (83 percent frequency) with concentrations ranging from 2.9 to 53 µg/L. All chromium concentrations and MDLs are less than the ESL of 64 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Chromium was detected in all two unfiltered pore water samples (100 percent frequency) at concentrations of 3.7 and 7.7 µg/L. Chromium concentrations in unfiltered samples are less than the ESL of 64 µg/L.

Seep/Spring. Chromium was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.24 to 20 µg/L. Chromium was detected in all four filtered seep/spring samples (100 percent frequency) with concentrations ranging from 0.55 to 19 µg/L. All chromium concentrations and MDLs are less than the ESL of 64 µg/L.

Surface Water. Chromium was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 0.17 to 0.21 µg/L. Chromium concentrations in unfiltered samples are less than the ESL of 64 µg/L. All MDLs are less than the ESL.

3.3.4.3 Copper

Groundwater. Copper was detected in 37 of 55 unfiltered groundwater samples (67 percent frequency) with concentrations ranging from 0.20 to 2.7 µg/L. Copper was detected in 7 of 53 filtered groundwater samples (13 percent frequency) with concentrations ranging from 0.25 to 5.6 µg/L. All chromium concentrations and MDLs are less than the ESL of 10 µg/L.

Aquifer Tubes. Copper was detected in 2 of 14 unfiltered aquifer tube samples (14 percent frequency). Copper concentrations in unfiltered samples are 5.0 and 52 µg/L. Of the two detected results, one sample was reported with a concentration greater than the ESL of 10 µg/L. Copper was detected at location AT-B-3-D (52 µg/L).

Copper was detected in 1 of 19 filtered aquifer tube samples (5.3 percent frequency) at a concentration of 7.2 µg/L. Copper concentrations in filtered samples are less than the ESL of 10 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Copper was not detected in unfiltered pore water samples (two samples). All MDLs are less than the ESL of 10 µg/L.

Seep/Spring. Copper was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.20 to 0.73 µg/L. Copper was detected in three of four filtered seep/spring samples (75 percent frequency) with concentrations ranging from 0.23 to 1.1 µg/L. All copper concentrations and MDLs are less than the ESL of 10 µg/L.

Surface Water. Copper was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 0.54 to 1.3 µg/L. Copper concentrations in unfiltered samples are less than the ESL of 10 µg/L. All MDLs are less than the ESL.

3.3.4.4 Fluoride

Groundwater. Fluoride was detected in 31 of 61 unfiltered groundwater samples (51 percent frequency). Fluoride concentrations in unfiltered samples range from 39 to 307 µg/L. Of the 31 detected results, one sample was reported with a concentration greater than the ESL of 300 µg/L. Although the maximum

detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

Fluoride was detected in 24 of 26 filtered groundwater samples (92 percent frequency) with concentrations ranging from 75 to 267 µg/L. All fluoride concentrations and MDLs are less than the ESL of 300 µg/L.

Aquifer Tubes. Fluoride was detected in 36 of 48 unfiltered aquifer tube samples (75 percent frequency), with concentrations ranging from 25 to 205 µg/L. Fluoride was detected in one filtered aquifer tube sample (100 percent frequency) at a concentration of 94 µg/L. All fluoride concentrations and MDLs are less than the ESL of 300 µg/L.

Pore Water. Fluoride was not detected in unfiltered pore water samples (two samples). All MDLs are less than the ESL of 300 µg/L.

Seep/Spring. Fluoride was detected in all four unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 93 to 190 µg/L. Fluoride concentrations in unfiltered samples are less than the ESL of 300 µg/L.

Surface Water. Fluoride was detected in four of six unfiltered surface water samples (67 percent frequency) with concentrations ranging from 88 to 91 µg/L. All fluoride concentrations and MDLs are less than the ESL of 300 µg/L.

3.3.4.5 Cr(VI)

Groundwater. Cr(VI) was detected in 59 of 83 unfiltered groundwater samples (71 percent frequency). Cr(VI) concentrations in unfiltered samples range from 2.4 to 64 µg/L. Of the 59 detected results, 44 samples were reported with concentrations greater than the ESL of 10 µg/L.

Cr(VI) was detected in 28 of 32 filtered groundwater samples (88 percent frequency). Cr(VI) concentrations in filtered samples range from 2.7 to 58 µg/L. Of the 28 detected results, 25 samples were reported with concentrations greater than the ESL of 10 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Cr(VI) was detected in 109 of 126 unfiltered aquifer tube samples (87 percent frequency). Cr(VI) concentrations in unfiltered samples range from 2.8 to 78 µg/L. Of the 109 detected results, 67 samples were reported with concentrations greater than the ESL of 10 µg/L.

Cr(VI) was detected in 68 of 75 filtered aquifer tube samples (91 percent frequency). Cr(VI) concentrations in filtered samples range from 2.6 to 48 µg/L. Of the 68 detected results, 34 samples were reported with concentrations greater than the ESL of 10 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Cr(VI) was detected in all two unfiltered pore water samples (100 percent frequency). Cr(VI) concentrations in unfiltered samples range from 13 to 24 µg/L. Cr(VI) concentrations in unfiltered samples are greater than the ESL of 10 µg/L.

Surface Water. Cr(VI) was not detected in unfiltered surface water samples (two samples). All MDLs are less than the ESL of 10 µg/L.

3.3.4.6 Iron

Groundwater. Iron was detected in 16 of 20 unfiltered groundwater samples (80 percent frequency) with concentrations ranging from 21 to 347 µg/L. Iron was detected in 17 of 47 filtered groundwater samples (36 percent frequency) with concentrations ranging from 9.5 L to 61 µg/L. All iron concentrations and MDLs are less than the ESL of 1,000 µg/L.

Aquifer Tubes. Iron was detected in 18 of 20 unfiltered aquifer tube samples (90 percent frequency). Iron concentrations in unfiltered samples range from 25 to 1,890 µg/L. Of the 18 detected results, one sample was reported with a concentration greater than the ESL of 1,000 µg/L. Iron was detected at location C7782 (1,890 µg/L).

Iron was detected in 14 of 24 filtered aquifer tube samples (58 percent frequency). Iron concentrations in filtered samples range from 14 to 4,610 µg/L. Of the 14 detected results, one sample was reported with a concentration greater than the ESL of 1,000 µg/L. Iron was detected at location 06-D (4,610 µg/L), and flagged with a "Y" review qualifier indicating the result is suspect.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Iron was detected in all two unfiltered pore water samples (100 percent frequency) at concentrations of 58 and 805 µg/L. Iron concentrations in unfiltered samples are less than the ESL of 1,000 µg/L.

Seep/Spring. Iron was detected in one filtered seep/spring sample (100 percent frequency) at a concentration of 60 µg/L. The single iron concentration in the filtered sample is less than the ESL of 1,000 µg/L.

Surface Water. Iron was detected in all two unfiltered surface water samples (100 percent frequency) at concentrations of 33 and 42 µg/L. Iron concentrations in the unfiltered samples are less than the ESL of 1,000 µg/L.

3.3.4.7 Lead

Groundwater. Lead was detected in 11 of 48 unfiltered groundwater samples (23 percent frequency) with concentrations ranging from 0.21 to 0.87 µg/L. Lead was detected in 1 of 40 filtered groundwater samples (2.5 percent frequency) at a concentration of 0.32 µg/L. All lead concentrations and most MDLs are less than the ESL of 2.1 µg/L.

Pore Water. Lead was detected in one of two unfiltered pore water samples (50 percent frequency). One sample was reported with a concentration greater than the ESL of 2.1 µg/L. Lead was detected at location RCBRA 2A AQ (2.7 µg/L).

Seep/Spring. Lead was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.025 to 0.96 µg/L. Lead was detected in all three filtered seep/spring samples (100 percent frequency) with concentrations ranging from 0.034 to 0.60 µg/L. All lead concentrations are less than the ESL of 2.1 µg/L.

Surface Water. Lead was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 0.019 to 0.033 µg/L. All lead concentrations and MDLs are less than the ESL of 2.1 µg/L.

3.3.4.8 Manganese

Groundwater. Manganese was detected in 42 of 55 unfiltered groundwater samples (76 percent frequency). Manganese concentrations in unfiltered samples range from 4.9 to 236 µg/L. Of the 42 detected results, 10 samples were reported with concentrations greater than the ESL of 120 µg/L.

Manganese was detected in 33 of 53 filtered groundwater samples (62 percent frequency). Manganese concentrations in filtered samples range from 1.8 to 661 µg/L. Of the 33 detected results, 10 samples were reported with concentrations greater than the ESL of 120 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Manganese was detected in 16 of 20 unfiltered aquifer tube samples (80 percent frequency), with concentrations ranging from 4.0 to 96 µg/L. Manganese concentrations in unfiltered samples are less than the ESL of 120 µg/L. Manganese was detected in 18 of 24 filtered aquifer tube samples (75 percent frequency). Manganese concentrations in filtered samples range from 0.10 to 198 µg/L. Of the 18 detected results, one sample was reported with a concentration greater than the ESL of 120 µg/L. Manganese was detected at location 06-D (198 µg/L) and flagged with a "Y" review qualifier, indicating the result was suspect.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Manganese was detected in all two unfiltered pore water samples (100 percent frequency). Manganese concentrations in unfiltered samples range from 2.1 to 250 µg/L. Of the two detected results, one sample was reported with concentrations greater than the ESL of 120 µg/L. Manganese was detected at location RCBRA 2A AQ (250 µg/L).

Seep/Spring. Manganese was detected in all eight unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.85 µg/L to 1.6 µg/L. Manganese was detected in one of two filtered seep/spring samples (50 percent frequency) at a concentration 1.3 µg/L. All manganese concentrations and MDLs are less than the ESL of 120 µg/L.

Surface Water. Manganese was detected in all nine unfiltered surface water samples (100 percent frequency) with concentrations ranging from 0.86 to 2.7 µg/L. All manganese concentrations are less than the ESL of 120µg/L.

3.3.4.9 Mercury

Groundwater. Mercury was not detected in unfiltered groundwater samples (48 samples). Mercury was detected in 2 of 40 filtered groundwater samples (5 percent frequency). Mercury concentrations in filtered samples are 0.092 and 0.17 µg/L. The two mercury concentrations were detected at monitoring well 199-B2-14 and flagged with "BD" and "B" laboratory qualifiers. All mercury concentrations and MDL are greater than the ESL of 0.012 µg/L.

Pore Water. Mercury was not detected in unfiltered pore water samples (two samples). All MDLs are greater than the ESL of 0.012 µg/L.

Seep/Spring. Mercury was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 2.9×10^{-4} to 4.8×10^{-4} µg/L. Mercury was detected in one filtered seep/spring sample (100 percent frequency) at a concentration of 5.0×10^{-4} µg/L. All mercury concentrations are less than the ESL of 0.012 µg/L.

Surface Water. Mercury was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 3.3×10^{-4} to 5.1×10^{-4} µg/L. All mercury concentrations are less than the ESL of 0.012 µg/L. All MDLs are greater than the ESL.

3.3.4.10 Nitrate

Groundwater. Nitrate was detected in 60 of 61 unfiltered groundwater samples (98 percent frequency). Nitrate concentrations in unfiltered samples range from 1,470 to 44,200 µg/L. Of the 60 detected results, 47 samples were reported with concentrations greater than the ESL of 7,100 µg/L. Nitrate was detected in nine samples with concentrations greater than the Hanford Site background level of 26,871 µg/L.

Nitrate was detected in all 26 filtered groundwater samples (100 percent frequency). Nitrate concentrations in filtered samples range from 1,080 to 13,200 µg/L. Of the 26 detected results, 18 samples were reported with concentrations greater than the ESL of 7,100 µg/L. Although the maximum detected concentration was greater than the ESL, nitrate concentrations are less than the Hanford Site background level of 26,871 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Nitrate was detected in all 48 unfiltered aquifer tube samples (100 percent frequency). Nitrate concentrations in unfiltered samples range from 1,880 to 45,200 µg/L. Of the 48 detected results, 42 samples were reported with concentrations greater than the ESL of 7,100 µg/L. Nitrate was detected in four samples with concentrations greater than the Hanford Site background level of 26,871 µg/L.

Nitrate was detected in one filtered aquifer tube sample (100 percent frequency) at a concentration of 9,520 µg/L. Although the maximum detected concentration was greater than the ESL, the single nitrate concentration is less than the Hanford Site background level of 26,871 µg/L.

3.3.4.11 Nitrite

Groundwater. Nitrite was detected in 1 of 61 unfiltered groundwater samples (1.6 percent frequency). The single nitrite concentration in unfiltered samples was reported at monitoring well 199-B2-16 (348 µg/L). The single nitrite concentration is greater than the ESL of 246 µg/L.

Nitrite was detected in 5 of 26 filtered groundwater samples (19 percent frequency), with concentrations ranging from 29 to 232 µg/L. Nitrite concentrations in filtered samples are less than the ESL of 246 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Nitrite was detected in 3 of 48 unfiltered aquifer tube samples (6.3 percent frequency), with concentrations ranging from 85 to 174 µg/L. Nitrite was not detected in filtered aquifer tube samples (one sample). All nitrite concentrations and MDLs are less than the ESL of 246 µg/L.

3.3.4.12 Nitrogen in Nitrate

Pore Water. Nitrogen in nitrate was detected in all two unfiltered pore water samples (100 percent frequency) with concentrations of 580 and 1,348 µg/L. Nitrogen in nitrate concentration in unfiltered samples are less than the ESL of 1,600 µg/L.

Seep/Spring. Nitrogen in nitrate was detected in all four unfiltered seep/spring samples (100 percent frequency). Nitrogen in nitrate concentrations in unfiltered samples ranged from 92 to 10,500 µg/L. Of the four detected results, three samples were reported with concentrations greater than the ESL of 1,600 µg/L. Nitrogen in nitrate was detected at location 100-B Spring 37-1 (3,400 and 10,500 µg/L), and 100-B Spring 39-2 (4,800 µg/L).

Surface Water. Nitrogen in nitrate was detected in one of two unfiltered surface water samples (50 percent frequency) at a concentration of 208 µg/L. Nitrogen in nitrate concentrations and MDLs are less than the ESL of 1,600 µg/L.

3.3.4.13 Radium-226

Groundwater. Radium-226 was detected in 9 of 16 unfiltered groundwater samples (56 percent frequency). Radium-226 concentrations in unfiltered samples range from 32 to 310 pCi/L. All nine detected results were reported with concentrations greater than the ESL of 4.1 pCi/L.

Radium-226 was detected in 12 of 17 filtered groundwater samples (71 percent frequency). Radium-226 concentrations in unfiltered samples range from 38 to 180 pCi/L. All 12 detected results were reported with concentrations greater than the ESL of 4.1 pCi/L.

Pore Water. Radium-226 was not detected in unfiltered pore water samples (two samples). All MDLs are less than the ESL of 4.1 pCi/L.

Surface Water. Radium-226 was not detected in unfiltered surface water samples (two samples). All MDLs are less than the ESL of 4.1 pCi/L.

3.3.4.14 Radium-228

Groundwater. Radium-228 was detected in 2 of 48 unfiltered groundwater samples (4.2 percent frequency). Radium-228 concentrations in unfiltered samples are 39 pCi/L. All two detected results were reported with concentrations greater than the ESL of 3.4 pCi/L. Radium-228 was detected at monitoring well 199-B3-51(39 pCi/L) during two sampling rounds.

Radium-228 was detected in 1 of 20 filtered groundwater samples (5 percent frequency). The single radium-228 concentration in unfiltered samples was 30 pCi/L. Radium-228 was detected at monitoring well 199-B2-16 (30 pCi/L).

Most MDLs are less than the ESL.

Pore Water. Radium-228 was not detected in unfiltered pore water samples (two samples). All MDLs are less than the ESL of 3.4 pCi/L.

Surface Water. Radium-228 was not detected in unfiltered surface water samples (two samples). All MDLs are less than the ESL of 3.4pCi/L.

3.3.4.15 Selenium

Groundwater. Selenium was detected in 38 of 48 unfiltered groundwater samples (79 percent frequency), with concentrations ranging from 0.52 to 4.2 µg/L. All selenium concentrations in unfiltered samples are less than the ESL of 5.0 µg/L. All MDLs are less than the ESL.

Selenium was detected in 26 of 40 filtered groundwater samples (65 percent frequency). Selenium concentrations in filtered samples range from 0.62 to 5.2 µg/L. Of the 26 detected results, 1 sample was reported with a concentration greater than the ESL of 5.0 µg/L. Although the maximum detected concentration is greater than the ESL, selenium concentrations are less than the Hanford Site background level of 11 µg/L.

Pore Water. Selenium was not detected in unfiltered pore water samples (two samples). All MDLs are less than the ESL of 5.0 µg/L.

Seep/Spring. Selenium was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.18 to 1.3 µg/L. Selenium was detected in all three filtered seep/spring samples (100 percent frequency) with concentrations ranging from 0.25 to 1.2 µg/L. All selenium concentrations are less than the ESL of 5.0 µg/L.

Surface Water. Selenium was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 0.17 to 0.23 µg/L. Selenium concentrations in unfiltered samples are less than the ESL of 5.0 µg/L. All MDLs were greater than the ESL.

3.3.4.16 Uranium

Groundwater. Uranium was detected in all 47 unfiltered groundwater samples (100 percent frequency). Uranium concentrations in unfiltered samples range from 0.25 to 7.6 µg/L. Of the 47 detected results, 4 samples were reported with concentrations greater than the ESL of 5.0 µg/L. Although the maximum detected concentration is greater than the ESL, uranium concentrations are less than the Hanford Site background level of 9.9 µg/L.

Uranium was detected in 6 of 13 filtered groundwater samples (46 percent frequency) with concentrations ranging from 0.83 to 1.4 µg/L. Uranium concentrations in filtered samples are less than the ESL of 5.0 µg/L.

Pore Water. Uranium was not detected in unfiltered pore water samples (two samples). All MDLs are greater than the ESL of 5.0 µg/L.

Seep/Spring. Uranium was detected in all eight unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.49 to 0.55 µg/L. Uranium was detected in one filtered seep/spring sample (100 percent frequency) at a concentration of 0.51 µg/L. All uranium concentrations are less than the ESL of 5.0 µg/L.

Surface Water. Uranium was detected in seven of nine unfiltered surface water samples (78 percent frequency) with concentrations ranging from 0.48 to 0.51 µg/L. Uranium concentrations in unfiltered samples are less than the ESL of 5.0 µg/L. All MDLs were greater than the ESL.

3.3.4.17 Zinc

Groundwater. Zinc was detected in 40 of 55 unfiltered groundwater samples (73 percent frequency). Zinc concentrations in unfiltered samples range from 2.6 to 165 µg/L. Of the 40 detected results, 2 samples were reported with concentrations greater than the ESL of 90 µg/L. Zinc was detected at monitoring well 199-B2-16 (165 and 93 µg/L).

Zinc was detected in 29 of 53 filtered groundwater samples (55 percent frequency). Zinc concentrations in filtered samples range from 1.7 to 178 µg/L. Of the 29 detected results, 1 sample was reported with a concentration greater than the ESL of 90 µg/L. Zinc was detected at monitoring well 199-B2-16 (178 µg/L).

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Zinc was detected in 11 of 20 unfiltered aquifer tube samples (55 percent frequency). Zinc concentrations in unfiltered samples range from 1.8 to 292 µg/L. Of the 11 detected results, 3 samples were reported with concentrations greater than the ESL of 90 µg/L. Zinc was detected at locations 06-M, 04-D, and 05-M with concentrations greater than the ESL.

Zinc was detected in 13 of 24 filtered aquifer tube samples (54 percent frequency). Zinc concentrations in the filtered sample range from 1.6 to 376 µg/L. Of the 13 detected results, 3 samples were reported with

concentrations greater than the ESL of 90 µg/L. Zinc was reported at locations 06-M, 04-D, and 05-M with concentrations greater than the ESL.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Zinc was detected in all two unfiltered pore water samples (100 percent frequency) at concentrations of 1.7 and 11 µg/L. Zinc concentrations in unfiltered samples are less than the ESL of 90 µg/L.

Seep/Spring. Zinc was detected in all 11 unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 0.51 to 1.2 µg/L. Zinc was detected in three of four filtered seep/spring samples (75 percent frequency) with concentrations ranging from 0.77 to 1.2 µg/L. All zinc concentrations and MDLs are less than the ESL of 90 µg/L.

Surface Water. Zinc was detected in all nine unfiltered surface water samples (100 percent frequency) with concentrations ranging from 0.51 to 1.3 µg/L. Zinc concentrations in unfiltered samples are less than the ESL of 90 µg/L.

M3.4 Identification of Contaminants of Interest – Riparian Soil

COIs were identified using the same process that was used for water.

M3.4.1 Apply Exclusion Criteria

The analytes in riparian soil that do not have plant/invert ESLs are summarized in Tables M-25 and analytes that do not have a wildlife screening level are summarized in Table M-26. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Tables M-25 and M-26.

M3.4.2 Identify Nondetected Analytes

Analytes that were not detected in riparian soil samples and have a plant or invertebrate soil ESL are summarized in Table M-27. Analytes that were not detected in riparian soil samples but have a wildlife ESL are summarized in Table M-28. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Tables M-27 and M-28.

M3.4.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

A summary of the riparian soil analytes that do not exceed the lowest plant/invertebrate ESLs is provided in Table M-29. A summary of the riparian soil analytes that do not exceed the lowest wildlife ESLs is provided in Table M-30. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Tables M-29 and M-30.

M3.4.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than their plant/invert or wildlife ESLs. A summary of the riparian soil analytes that exceed the lowest plant/invertebrate ESLs is provided in Table M-31.

Thallium was detected in 2 of 20 riparian soil samples, both at a concentration of 0.75 milligrams per kilogram (mg/kg). Thallium was detected above the invert ESL of 0.46 mg/kg at the 100-BC intermediate sample location.

A summary of the riparian soil analytes that exceed the lowest wildlife ESLs is provided in Table M-32. As shown in Table M-32, aluminum, bis(2-ethylhexyl) phthalate, dieldrin, and vanadium are greater than the wildlife ESLs.

Aluminum was detected in 20 riparian soil samples with concentrations ranging between 4,210 and 7,100 mg/kg. Aluminum concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 11,800 mg/kg. In addition, aluminum is generally more bioavailable and toxic at low pHs (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]). The ecological soil screening levels (co-SSLs) for aluminum (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60]), identified potential toxicity in soils when the pH is 5.5 or less. All measurements of soil pH in the River Corridor are greater than the 5.5 threshold. Therefore, concentrations of aluminum are not likely bioavailable for uptake.

Bis(2-ethylhexyl)phthalate (BEHP) was detected in eight of nine riparian soil samples with concentrations ranging between 0.022 and 0.16 mg/kg. The maximum detected concentrations of BEHP is greater than the avian ESL of 0.14 mg/kg but below the mammalian ESL of 45.4 mg/kg., However, BEHP is considered to be a common laboratory contaminant, and is not related to the Hanford Site.

Dieldrin was detected in one of six riparian soil samples at a concentration of 0.22 mg/kg. Dieldrin was detected above the plant/invert ESL of 0.021 mg/kg at the RCBRA 2A riparian sample location.

Vanadium was measured in 20 riparian soil samples with concentrations ranging between 20 mg/kg and 58 mg/kg. Vanadium concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 85 mg/kg.

M3.5 Identification of Contaminants of Interest – Nearshore Sediment

Contaminants of interest were identified using the same process that was used for water.

M3.5.1 Apply Exclusion Criteria

The analytes in sediment that do not have an ESL are summarized in Table M-33. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table M-33.

M3.5.2 Identify Nondetected Analytes

Analytes that were not detected in sediment samples are summarized in Table M-34. Sampling dates and minimum and maximum MDLs are also provided in Table M-34.

M3.5.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

A summary of the sediment analytes that do not exceed the sediment screening levels is provided in Table M-35. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table M-35.

M3.5.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than sediment screening levels. A summary of the sediment analytes that exceed the lower threshold sediment screening levels is provided in Table M-36. Table M-36 shows that concentrations of six analytes are greater than their sediment screening value and are listed below:

- Antimony, barium, chromium, manganese, phosphorous, and thallium

In at least one sediment sample, there were concentrations of metals (antimony, barium, cadmium, chromium, manganese, phosphorus, thallium, and zinc) detected at concentrations higher than an ESL.

The analytes listed above that exceed the lower threshold sediment screening value are subsequently compared to the upper threshold sediment screening values; the results of this comparison are shown in Table M-37. Table M-37 show that antimony and chromium exceed the upper threshold sediment screening values.

Antimony was detected in two of five samples at concentrations of 0.43 and 0.65 mg/kg. Antimony was detected above the upper threshold sediment screening value of 0.6 mg/kg at sampling location 100-B Spring 38-3, and flagged with a "C" qualifier indicating the result was reported in the laboratory method blank.

Chromium was detected in six samples with concentrations ranging from 7.0 to 96 mg/kg. Of the six detections, one sample was reported with a concentration greater than the upper threshold sediment screening value of 95 mg/kg. Chromium was detected above the upper threshold sediment screening value at sampling location 100-B Spring 37-1.

A discussion of the ecological risk considerations associated with this result is presented in Section M4.

M3.6 Data Evaluation Summary

A range of inorganic and radionuclide contaminants were detected in near-river groundwater samples collected from the 100-BC-5 OU. In many cases, these contaminants also could be detected in aquifer tube, pore water, spring/seep, and surface water samples. In most cases, the analytical results that were most relevant to assessing aquatic water quality (that is, from filtered analyses) were at concentrations below aquatic criteria. In other cases where concentrations higher than aquatic criteria were observed, these results were associated with analytical data quality issues such as presence of contamination in blank samples, or elevated detection limits relative to the criteria.

The analytical results addressed in this evaluation did not provide evidence that contaminants from Hanford Site soils or groundwater or associated with Hanford Site operations evaluated in this appendix have potentially been discharged to riparian or nearshore media, or to the Columbia River. A more detailed discussion of potential ecological risks in the context of abiotic and biotic media evaluations and potential contributions to these risks from the Hanford Site is presented in Section M4.

M4 Summary of Ecological Risks

Ecological risks in riparian and nearshore areas were assessed as part of the RCBRA (RCBRA Report [DOE/RL-2007-21]). This risk evaluation in this appendix incorporates the results from the assessment of ecological risks in the riparian and nearshore areas based on the data evaluation and calculations performed in the RCBRA.

The RCBRA Report (DOE/RL-2007-21) evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative nearshore study sites. The study sites were selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment).

M4.1 Risks to Terrestrial Plants

As shown in Table 5-61 of the RCBRA (DOE/RL-2007-21), central tendency estimates (CTEs) of some COPECs in riparian soil collected across the Hanford Reach (that is, estimate of central tendency across both 100 and 300 areas) exceeded literature-based plant SSL concentrations developed for the RCBRA (DOE/RL-2007-21), indicating that the potential for effects in plants warranted further evaluation. CTEs for arsenic, chromium, lead, vanadium, and zinc in riparian soil were greater than SSLs across the

Hanford Site; in the 100-BC riparian study areas (2a) concentrations of arsenic, vanadium, and zinc were higher than the benchmark value for protection of terrestrial plants (RCBRA Report [DOE/RL-2007-21], Tables 5-61). SSLs are literature-based values compiled from state and federal criteria and were initially presented in both the RCBRA Report (DOE/RL-2007-21) and in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). For risk-driving inorganics, bioassays were collected using a representative native plant species (Sandberg's bluegrass [*Poa secunda*]) to develop site-specific toxicity thresholds. These refined values were presented in the RCBRA Report (DOE/RL-2007-21) and used to establish plant PRGs. Additional bioassays were conducted in 2011 on the same species with a broader concentration gradient of inorganic constituents to further refine toxicity thresholds and establish PRGs as described in ECF Hanford 11-0158. The organic SSLs and inorganic PRGs were identified as the ESLs presented in this RI/FS as summarized in Table M-3.

Measurements of all chemicals within the riparian soils of the 100-BC OUs were below plant ESLs (Table M-31). Also, other lines of evidence obtained through seven different measures in bioassay testing indicate that COPECs may not adversely affect plants at riparian sites, including those at the rare plant sites that performed better in bioassays compared with reference soils. Bioassays showed no significant differences in plant seed germination, root length, stem height, root biomass, or shoot biomass between riparian study sites and reference sites. Some chemicals were detected in plant tissues, but the concentrations of the chemicals were statistically different between riparian study sites and reference site concentrations for only four chemicals: barium, copper, thallium, and zinc (Table 5-32, RCBRA Report [DOE/RL-2007-21]). Similar to the upland plant data, chemical concentrations found in riparian plant tissues did not correlate to those in riparian soil. Therefore, although soil concentrations are greater than plant SSLs across the Hanford Site as a whole, for some COPECs the weight attributed to this line of evidence is low and comparisons to ESLs do not overwhelm the other lines of evidence, which do not indicate risks to plants in riparian soils. Although several analytes were detected in plant tissue during the RCBRA (DOE/RL-2007-21), and statistical differences between riparian study area sites and reference site concentrations were noted, there were no statistically significant relationships of chemical concentrations in plant tissue and soil. Therefore, no chemicals in the 100-BC area riparian soils warrant further evaluation in the FS based on risks to terrestrial plants.

M4.2 Risks to Aquatic Plants

Potential effects on aquatic plants were evaluated through comparison of sediment and pore water concentrations to screening levels developed for the RCBRA Report (DOE/RL-2007-21) and CRC (DOE/Rl-2010-117) and results of a bioassay in sediment (DOE/RL-2007-21). The combined pore water and sediment RCBRA COECs were identified as cadmium, total chromium, Cr(VI), manganese, and uranium, warranting further evaluation for potential effects on aquatic plants, as noted in Section 8.5.1.1 of the RCBRA Report (DOE/RL-2007-21). The Executive Summary of the CRC (DOE/RL-2010-117) identified the final COECs for pore water and sediment within 100-BC-5 as aluminum, chromium, Cr(VI), and lead.,

Laboratory bioassays (that is, toxicity tests) were conducted with field-collected sediments. Some significant relationships were determined with observed response within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, there were clear measures of exposure (that is, accumulation into plants), primarily for inorganic COPECs that were detected in pore water and sediment. However, of the significant relationships determined, none was with COPECs for which pore water concentrations were greater than aquatic plant benchmarks. Further, no risks to aquatic plants were noted based on toxicity testing. Although the analysis represents only one season of sampling and analysis, the weight of the available data does not suggest risk to aquatic plants.

For the 100-BC Area nearshore sampling sites, antimony and chromium were detected in sediment at concentrations greater than the upper threshold sediment biota ESL (Table M-36). Although chromium and manganese were identified as COECs for aquatic plants in the RCBRA, this determination was based on data collected outside the influence of the 100-BC Area (RCBRA Report [DOE/RL-2007-21], Figures 8-30 and 8-34). Because the RCBRA Report (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) did not identify these analytes as COECs for aquatic plants based on concentrations within the 100-BC Area, additional evaluation for risks to aquatic plants is not warranted for these COPECs within 100-BC. These sediment COPECs are discussed in more detail below with respect to risks to aquatic invertebrates.

From the 100-BC nearshore sampling sites, the pore water concentrations of aluminum, Cr(VI), lead, and manganese were greater than the chronic ambient water quality criteria (Table M-22). No other chemicals in pore water samples from the 100-BC groundwater OU exceeded water ESLs. The 100-BC nearshore water data are further discussed in Section M3.3.4 of this appendix. The RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) pore water COECs, as well as 100-BC nearshore pore water COPECs, are discussed in more detail below with respect to potential contributions from the 100-BC riparian area to risks to aquatic plants in the Columbia River.

Aluminum – Concentrations of aluminum were elevated in pore water samples presented in the CRC (DOE/RL-2010-117) for the 100-HR-3, 100-BC-5, and 300-FF-5 OUs. Concentrations within the 100-BC area exceeded the ESL in filtered aquifer tubes (five of five samples) and groundwater samples (1 of 40 samples) (Table M-24). The single filtered seep sample did not exceed the ESL. Filtered pore water was not analyzed for aluminum; however, one of two unfiltered pore water samples was detected below the ESL. Thus, evidence is not sufficient to suggest aluminum within the 100-BC groundwater OU wells within the vicinity of 100-BC are contributing to concentrations of aluminum observed in pore water at locations within the reach of the Columbia River adjacent to or downstream from the 100-BC nearshore area.

Cr(VI) – Concentrations of Cr(VI) were elevated in pore water samples presented in the CRC (DOE/RL-2010-117) for the 100-HR-3, 100-FR-3, 200-PO-1, 100-KR-3, 100-NR-2, and 100-BC-5 OUs and in the RCBRA (DOE/RL-2007-21). Within 100-BC, nearshore filtered samples exceeded the ESL in aquifer tubes (34 of 75 samples) and groundwater wells (25 of 32 samples). The ESL was also exceeded in both unfiltered pore water samples. Given the pathway from groundwater to the aquifer tubes and ultimately pore water, there is a clear pathway of Cr(VI) originating from the 100-BC-5 OU.

Lead – Concentrations of lead were elevated in pore water samples presented in the CRC (DOE/RL-2010-117), for the 100-HR-3, 100-BC-5, 200-PO-1, and 300-FF-5 OUs. Filtered concentrations within the 100-BC groundwater and seep samples were below the ESL. Pore water samples were not filtered but were below the ESL in one of two samples, which does not suggest 100-BC to be the source. Thus, the 100-BC Source OUs are not contributing to concentrations of lead observed in pore water at locations within the reach of the Columbia River downstream from points of entry from the 100-BC OUs.

Manganese – Concentrations of manganese were elevated in pore water samples presented in the RCBRA Report (DOE/RL-2007-21). No filtered seep samples within the 100-BC nearshore area report manganese. For filtered groundwater, 10 of 53 samples exceeded the ESL. For filtered aquifer tubes, 1 of 24 samples exceeded the ESL. Pore water samples were not filtered but were below the ESL in one of two samples, which does not suggest 100-BC to be the source. Thus, with concentrations in aquifer tubes not consistently exceeding the ESL, it appears that the 100-BC Source OUs are not contributing to concentrations of manganese observed in pore water at locations within the reach of the Columbia River downstream from points of entry from the 100-BC OUs.

Uranium – Although concentrations of uranium were elevated in pore water samples presented in the RCBRA Report (DOE/RL-2007-21)., concentrations within the 100-BC riparian and nearshore aquatic media were below water quality criteria, save four unfiltered groundwater samples that were below background. Thus, uranium within the 100-BC Source OUs is not contributing to concentrations of uranium observed in pore water at locations within the reach of the Columbia River.

M4.3 Risks to Terrestrial Invertebrates

Thallium concentrations were detected at two locations in the 100-BC riparian study sites in exceedance of Hanford Site-specific ESLs in soil (Table M-31). However, Table 5-29 of the RCBRA Report (DOE/RL-2007-21), indicates that thallium concentrations were below background, and thus are not a source contributing to risks to terrestrial invertebrates. Measurements of all other chemicals within the riparian soils of the 100-BC Source OUs were below soil invertebrate ESLs.

Concentrations of chromium, mercury, TPH-diesel, and zinc in riparian soil exceeded benchmarks developed for the RCBRA (DOE/RL-2007-21) that are protective of terrestrial invertebrates; in the 100-BC riparian study areas (B/C Pilot and 2a), concentrations of chromium and zinc were higher than the benchmark value for protection of terrestrial invertebrates (RCBRA [DOE/RL-2007-21], Tables 5-69 and 5-70). However, none of the concentrations were above Hanford Site-specific ESLs protective of terrestrial invertebrates (Table M-31 of this appendix).

Terrestrial invertebrate tissue concentrations, which provide an indication of contaminant uptake and bioavailability, were measured at River Corridor study sites and reference locations and some, but not all, COPECs were detected in terrestrial invertebrates. Statistical differences were found between RCBRA (DOE/RL-2007-21) terrestrial invertebrate tissue concentrations for some chemicals between study site and reference site soils. However, this line of evidence was ranked low in the RCBRA (DOE/RL-2007-21) because of the lack of detections in invertebrate tissue for riparian COPECs and the possibility of bias as a result of sample collection methods.. Statistical differences in tissue concentrations of mercury and zinc in terrestrial invertebrates were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor, and should not be inferred as a relationship that is specific for 100-BC. However, there is insufficient evidence for chemicals in general of a correlation between tissue concentrations in terrestrial invertebrates and concentrations in soil (DOE/RL-2007-21). Based on this analysis, no chemicals in riparian soil warrant further evaluation in the FS because of risks to terrestrial invertebrates.

The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial invertebrates from exposure to island and riparian soils.

M4.4 Risks to Aquatic Invertebrates

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, the results of bioassays, and comparison of sediment and water concentrations to benchmarks such as ESLs.

M4.4.1 Abiotic Media Concentrations Compared to Literature Values

The final COECs for pore water in CRC within the 100-BC-5 OU were identified as aluminum, Cr(VI), and lead, as noted in the Executive Summary of the CRC (DOE/Rl-2010-117). Pore water concentrations at study sites were greater than chronic water standards or criteria for three COECs (Cr(VI), manganese, and uranium) (RCBRA [DOE/RL-2007-21], Sections 8.5.1.1 and 8.5.1.2). However, there are significant uncertainties relative to any of the conclusions based on pore water sampling because these abiotic measurements represent a single point measurement within a dynamic river system with daily and seasonal fluctuations and flow volumes that can shift the composition of the substrates that were sampled.

Thus, exceedances should not be ignored because they can be indicative of exposure an levels presenting a risk. But because of the uncertainty in the representativeness of the measurements as a result of the dynamic environment, the exceedances should be considered along with other data that identifies whether there is in fact an ongoing source of the measurements. The interpretation of pore water results as an indication of potential adverse effects to aquatic invertebrates is the same as that for aquatic plants, given that the ESLs are protective of both plants and aquatic invertebrates. Only Cr(VI) in the 100-BC-5 groundwater OU, which represents a potential source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS.

The RCBRA identified three COECs (cadmium, chromium, and manganese) in sediment for the River Corridor as a whole (RCBRA [DOE/RL-2007-21], Sections 8.5.1.1 and 8.5.1.2). Total chromium and Cr(VI) in sediment were also identified as COECs in the CRC (DOE/RL-2010-117). For sediment samples collected within the 100-BC nearshore (Table M-36), concentrations were greater than upper threshold ESLs for two chemicals (antimony and chromium). Given the uncertainty with representativeness mentioned above, a more detailed discussion of each of these five COECs/COPECs from the RCBRA (DOE/RL-2007-21), CRC (DOE/RL-2010-1117), and 100-BC nearshore sediment (Appendix L) is presented below.

Antimony – Antimony was detected in two of five samples within the 100-BC nearshore sediments. One detected concentration exceeds the upper threshold sediment ESL. However, the groundwater/seep/pore water analysis showed no substantial concentrations of antimony because concentrations were below both the ESL and background. Thus, concentrations were not likely from suspended solids in groundwater. Table 5-29 of the RCBRA Report (DOE/RL-2007-21) indicates that antimony concentrations across the Hanford Site riparian soils were not statistically different from riparian reference soil concentrations. All four detected soil concentrations within the 100-BC nearshore area (Table M-30) were below the sediment reference sites (DOE/RL-2007-21, Table 6-41). Therefore, antimony is not considered a COPC for the nearshore environment because there are no environmentally relevant concentrations of antimony in RCBRA nearshore sediment and no detections of antimony in 100-BC Area riparian soil concentrations greater than reference sediment concentrations for antimony (DOE/RL-2007-21). There is no complete or significant pathway for observed antimony concentrations in sediment from the 100-BC Source OUs or the 100-BC-5 OU.

Cadmium – Cadmium was detected in four of five samples within the 100-BC nearshore sediment; however, all four detections were below the lower threshold ESL. Table 5-29 of the RCBRA Report (DOE/RL-2007-21) indicates that cadmium concentrations across the Hanford Site riparian soils are greater than riparian reference soil concentrations. For the 100-BC Area riparian soils collected at sites 100-BC Pilot and 2a riparian sites, detected concentrations of cadmium (0.075 to 1.7 mg/kg) were lower than the maximum sediment reference concentration (2.2 mg/kg) presented in Table 6-40 of the RCBRA Report (DOE/RL-2007-21). Cadmium was not detected in the two pore water samples collected from the 100-BC site and all 11 detected seep samples were below water quality criteria. Table 6-40 of the RCBRA Report (DOE/RL-2007-21) indicates that the detected nearshore sediment study site concentrations of cadmium are not greater than the reference site concentrations. Cadmium is not considered a COPEC for the nearshore environment because 100-BC RCBRA riparian study site soil concentrations are not greater than 100-BC RCBRA nearshore sediment concentrations, and all nearshore riparian soil concentrations are below reference sediment concentrations and ESLs (DOE/RL-2007-21). There is no complete or significant pathway for observed cadmium concentrations in sediment from the 100-BC riparian area.

Total Chromium – Total chromium was identified as a COEC for the 100-Area in the CRC (DOE/Rl-2010-117) because of concentrations above a lowest observed effect concentration (LOEC) in three samples and in the RCBRA (DOE/RL-2007-21). Chromium was detected in all six sediment samples in the 100-BC nearshore environment, with two detections greater than the *screening level* of 72 mg/kg published in *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054), and one of those is above the cleanup level of 88 mg/kg in the same report. Chromium was detected in all 20 100-BC riparian soil samples. The maximum detect from the source OUs was 44.6 mg/kg. The three samples identified in the CRC above the *cleanup level* of 88 mg/kg (*Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* [Ecology Publication 11-09-054]) range from 122 to 275 mg/kg; thus, the measured concentrations do not originate from the 100-BC riparian soils or nearshore sediments where the maximum detect was just 96 mg/kg. As presented above in the detailed analysis of pore water, total chromium in groundwater is detected below the ESL and background, suggesting no potential source partitioning to sediments. There is no complete or significant pathway for observed total chromium concentrations in sediment from the 100-BC riparian area.

Cr(VI) – Cr(VI) is a known site contaminant of concern and was detected in 31 of 117 sediment samples in the 100 Areas reach of the Columbia River as part of the CRC (DOE/RL-2010-117), with a maximum of 7.38 mg/kg. It was also detected in nearshore sediment samples collected for the RCBRA at 0.92 mg/kg at 100-D (1 of 10 detects). It was not collected from 100-BC nearshore sediments (DOE/RL-2007-21). With no substantial toxicological data available with which to evaluate the bulk sediment measurements, this contaminant was identified as a COPEC in both reports.

Although there are acknowledged groundwater plumes of Cr(VI) that could serve as a potential source to sediments, Cr(VI) does not persist in natural aquatic environments such as those present in the Columbia River. Oxidation of Cr+3 to Cr+6 has been observed in soil and sediment under oxidizing conditions (EPA/600/R-07/140, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*). *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc). Appendix D: Chromium* (EPA-600-R-02-011) states that geochemical processes govern the reduction of Cr(VI) to chromium(III) in aquatic environments, and geochemical processes are critical to the attenuation of chromium in sediments. The presence of chromium(III) is strongly favored in natural waters and sediments because the concentrations of sediment constituents known to reduce Cr(VI) to chromium(III) generally far outweigh the concentrations of the few constituents known to oxidize chromium(III) to Cr(VI). Furthermore, once reduced, chromium(III) is very stable in aquatic environments and highly unlikely to oxidize to Cr(VI). Thus, chromium in sediments is more likely to be in its chromium(III) form than its Cr(VI) form ("Behavior of Chromium in Soils: V. Fate of Organically Complexed Cr(III) Added to Soil" [James and Bartlett, 1983]; "Chromium(iii) Oxidation by Delta-MnO_2.1. Characterization" [Fendorf and Zasoski, 1992]; "Fractionation and Oxidation of Chromium in Tannery Waste- and Sewage-Sludge-Amended Soils" [Milacic and Stupar, 1995]; "The reactivity of seven Mn-oxides with Cr^{3+}aq: A comparative analysis of a complex, environmentally important redox reaction" [Weaver and Hochella, 2003]).

More detail regarding the Cr(VI) in sediment and the environment within the Columbia River and particularly at groundwater upwelling locations is found in *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398) and *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (WCH-380).

Manganese – Manganese was identified as a COEC for sediment along the River Corridor (DOE/RL-2007-21). Manganese was detected in all five samples within the 100-BC nearshore sediments. Two of the detected concentrations exceed the lower threshold ESL but did not exceed the upper threshold ESL. This suggests effects are not likely. The maximum study site sediment concentration in the RCBRA was 920 mg/kg at Sr6, which was not within the 100-BC area (DOE/RL-2007-21). Furthermore, all manganese concentrations are rarely greater than the maximum reference site concentration (Figure 8-34). The groundwater/seep/pore water analysis showed no substantial concentrations of manganese related to the 100-BC Area. Thus, concentrations were not likely from suspended solids in groundwater. Manganese was detected in all 20 soil samples collected (Table M-30). Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that manganese concentrations across the Hanford Site riparian soils were not statistically different from riparian reference soil concentrations or background. There is no complete or significant pathway for observed manganese concentrations in sediment from the 100-BC riparian area.

M4.4.2 Direct Toxicity Measures

Risks to aquatic macroinvertebrates based on toxicity testing showed some relationship with confounding factors and some COPECs. Histopathology measures differed in study sites compared to reference sites; these measures also showed some negative relationships with COPECs. Sediment bioassays for the100-BC Area showed no difference in growth, or higher levels of amphipod (*Hyalella azteca*) growth relative to reference sites. Likewise, survival and reproduction tests on water fleas in pore water showed no difference at two sites representing 100-BC (2a Aq and 2b Aq), relative to reference sites. Correlation between abiotic media chemistry and any observed differences in measured effects from both bioassays was conducted across the entire Hanford Reach. Mercury was the only COPEC with a significant correlation that showed a potential negative effect with a significant regression; however, mercury was below sediment ESLs at the 100-BC study sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites, but there was no correlation of clam survival with COPECs. Together these measures do not indicate substrate concentrations were toxic. However, they do represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations.

M4.4.3 Community Structure Measures

Key community metrics do not suggest that contaminant-related impacts to benthic macroinvertebrates are evident in aquatic study sites as a group, as evident by the comparison of Ephemeroptera, Plecotera, and Trichoptera (EPT) data from study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.

M4.4.4 Measures of Exposure

Within the RCBRA (DOE/RL-2007-21), clear measures of exposure (accumulation), primarily for inorganic COPECs, were detected in water, sediment, and tissues. There were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded.

Most histopathology measures of clams and mussels showed no significant differences between study sites and reference. Although there were some exceptions, COPEC concentrations generally did not correlate with differences in histopathology measures.

M4.4.5 Weight of Evidence

As stated previously, both the abiotic and biotic measures collected for the RCBRA (DOE/RL-2007-21) represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations. Abiotic measurements do exceed literature-based screening values for some COPECs, and this line of evidence is generally assigned the lowest weight given the lack of site-specificity in the literature-based values. Although biological measures give a different perspective than the chemistry, given the limited dataset and the uncertainty with full representation of seasonal measurements, the results of the chemistry cannot be ignored.

Of the key groundwater plume contaminants investigated, only Cr(VI) had concentrations of ecological relevance in the nearshore environment for the 100-BC Area. Cr(VI) in groundwater in the 100-BC-5 OU, which represents a potential ongoing source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS. This conclusion is applicable to both aquatic invertebrates and amphibians.

M4.5 Risk to Riparian Wildlife

For riparian soils, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and biological concentrations in bird or small mammal tissues are compared to ecological effects levels established for dietary ingestion or related to tissue residues. For selected COPECs (cadmium, chromium, lead, selenium, and PCBs), measured tissue concentrations in small mammals trapped in River Corridor study sites were not greater than reference areas (RCBRA Report [DOE/RL-2007-21], Table 5-48), and were less than available tissue effect levels (RCBRA Volume I [DOE/RL-2007-21], Page 5-91). Dietary exposure to terrestrial birds and mammals estimated using wildlife exposure models estimated for riparian concentrations across the River Corridor indicated potential exposure higher than lowest observed adverse effect level (LOAEL)-based SSL values for copper, selenium, vanadium, and zinc (DOE/RL-2007-21, Section 8.4.1.3). Only zinc was identified as a final COEC for riparian soil exposure to birds and mammals. However, concentrations of zinc in 100-BC, although greater than Hanford Site-wide background (67.8 mg/kg) (DOE/RL-2007-21, Table 2-9), fall below the ESL and within the reference study sites (336 mg/kg); therefore, they should not warrant further evaluation in the FS.

Most concentrations detected in riparian soils within the 100-BC fell below ESLs (in this case, specifically SSLs and PRGs described earlier) and do not warrant further evaluation in the FS. Four chemicals within riparian soils had concentrations above ESLs: aluminum, BEHP, dieldrin, and vanadium (Table M-32).

Aluminum – Sitewide aluminum concentrations were below background and within the reference study (RCBRA [DOE/RL-2007-21], Table 5-29). Although all 100-BC Area samples were above the ESLs for birds and mammals, the EPA's eco-SSL for aluminum (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60]) presents a clear discussion that toxicity is only identified in soils when the pH is 5.5 or less. Measures of pH in soils in the 100-BC Area are above 5.5; thus, aluminum toxicity to wildlife is not a concern.

Bis(2-ethylhexyl)phthalate – One of the nine samples analyzed for BEHP exceeded the avian ESL within the 100-BC Area. However, the ESL was derived using an unbound no observed adverse-effect level (NOAEL). Thus, no effects were observed at the maximum concentration tested and there were such limited data available that it is uncertain at what concentration effects in birds may be seen. BEHP is a common laboratory contaminant and there is no significant site use warranting this chemical as a constituent of significant concern. Given the lack of site use and the fact that concentrations are below

those estimated to pose a risk to other wildlife (mammals), toxic effects to avian wildlife at the concentrations measured are unlikely and require no further investigation.

Dieldrin – One (0.022 mg/kg) of six samples analyzed for dieldrin slightly exceeded the mammalian ESL (0.021 mg/kg) within the 100-BC Area. Although this single detection is the maximum concentration observed sitewide, the RCBRA broad scale assessment of ecological risks concludes that both CTE and reasonable maximum exposure (RME) exposures are less than the NOAELs and LOAELs for dieldrin and further evaluation is not required (RCBRA Report [DOE/RL-2007-21], Section 7.3.5.3).

Vanadium – The maximum detected concentration of 58.4 mg/kg for 100-BC was less than the site background of 85 mg/kg. Although the PRG was developed with a model using site-specific tissue data, it still included uncertainties. Thus, with concentrations being below background, potential toxic effects to wildlife are unlikely.

Within the RCBRA (DOE/RL-2007-21), information on dietary contaminant exposures was also compared to ecological effects levels for diet to assess risks to birds or mammals potentially exposed to contaminants in nearshore sediments, biota, and water. Only chromium was considered a final COEC. However, the single study site (2 m/7 ft) with which this risk was associated is within the 100-F/100-IU-2/100-IU-6 ROD Area and not within the 100-BC nearshore environment.

M4.6 Risk to Fish

No COECs in the RCBRA Report (DOE/RL-2007-21) or in the CRC (DOE/RL-2010-117) were identified for surface water exposures to fish.

The RCBRA (DOE/RL-2007-21) identified Cr(VI) pore water concentrations indicative of risk to fish and warranting additional consideration. The CRC (DOE/RL-2010-117) also indicated exceedances of water quality standards or criteria (aluminum, Cr(VI), and lead) in pore water. However, most other lines of evidence suggest that there is no unacceptable risk to fish in the Columbia River. In general across the River Corridor, fish were smaller (in length and mass) at study sites relative to reference sites. However, many factors confound or contribute to the size of fish captured, such as fishing pressure or ease of capture of the target size range. Correlation with capture size and chemical concentration or any other factor (for example, habitat, nutrient availability) was not possible because it was not considered as part of the original study design. No strong trends in fish histopathology were observed between those collected at study sites and those from reference site locations. No tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. There were no exceedances of tissue effects levels for nearshore aquatic COPECs measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues.

There are significant uncertainties relative to any of the conclusions based on pore water sampling. Further, all of these abiotic measurements represent a single point measurement within a dynamic river system with daily and seasonal fluctuations and flow volumes that can shift the composition of the substrates that were sampled. Exceedances should not be ignored because they can be indicative of exposure at levels presenting a risk. But because of the uncertainty in the representativeness of the measurements because of the dynamic environment, the exceedances should be considered along with other data that identifies whether there is in fact an ongoing source of the measurements.
The interpretation of pore water results as an indication of potential adverse affects to fish is the same as that for aquatic plants, given that the ESLs are protective of both plants and fish; only Cr(VI) in the 100-BC-5 groundwater OU in the 100-BC Area, which represents a potential source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS. Other COPECs detected in pore water above ambient water quality criteria do not appear to be an issue in groundwater or

aquifer tubes, suggesting that the 100-BC-5 groundwater OU is not the source of observed elevated concentrations.

M5 Conclusions

The purpose of preparing this CSM was to address, on a reactor decision area basis, the potential for Hanford Site contaminants in soil or groundwater to migrate to riparian or nearshore areas at concentrations that could be of concern for ecological receptors. This CSM supplements the analysis of River Corridor-wide ecological risks presented in the ecological risk assessment of the RCBRA (DOE/RL-2007-21). The RCBRA (DOE/RL-2007-21) identified on a site-wide basis some contaminants of ecological concern that warranted further evaluation. Based on the results of the further evaluation contained in this CSM, with the exception of Cr(VI), detected concentrations of contaminants in riparian or nearshore groundwater, seeps/springs, aquifer tubes, and pore water are not reliably detectable at levels of ecological concern, or are not associated with contaminated groundwater resulting from Hanford Site operations. For purposes of alternatives evaluation in the 100-BC FS, Cr(VI) in the 100-BC-5 groundwater OU should be considered the only COEC.

There are uncertainties in this evaluation related to analytical data quality. With the exception of most recently collected analytical data in groundwater, analytical methods had MDLs that were close to or higher than aquatic criteria; when methods with adequate detection limits are used, the results show that contaminant concentrations are less than aquatic criteria. In many cases where analytical results were higher than aquatic criteria, it was determined that the results were based on unfiltered samples. Unfiltered analytical results are inappropriate for comparison with aquatic criteria; in general, filtered analytical results were less than aquatic criteria. In some cases where concentrations were reported higher than aquatic criteria, further evaluation of the data revealed it was qualified because of the presence of blank contamination. The analytical detection limit considerations and data quality issues further support the conclusion that contaminant concentrations in water were not reliably detected above levels of ecological significance.

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